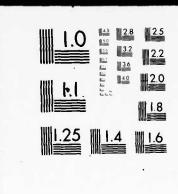
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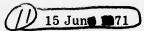
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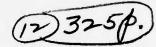
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INTERIM TECHNICAL REPORT, APPENDICES,





PRESENTED TO

Surveying and Geodesy Division USAETL Fort Belvoir, Virginia

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APPENDIX A DATA REDUCTION PRINCIPLES

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APPENDIX A DATA REDUCTION PRINCIPLES

1. PROBLEM FORMULATION

The simultaneous reduction method with constraints is achieved by finding values for all variables which minimize a functional comprised of the weighted sum of squares and differences between measured data and the observation model, and differences between the solution vector and a vector of apriori information about all of the parameters being estimated. In general if the vector Q is comprised of all of the parameters being estimated and the observational equation is given by:

$$M_{jk} = G_{jk}(Q)$$

where M_{jk} is the measured quantity at the j^{th} ground station of the k^{th} aircraft location.

The function G(Q) relates the parameters being estimated to the quantities being measured and, therefore, forms the observation equations for the system of data reduction. For the LRPDS the quantities being measured are range changes at each ground station location. The data from each ground station is then a sequence of time differences which represent the changes in propagation time for each read command received from the aircraft. By suitable scaling, these time differences may be considered as representing changes in range between the first received read command and any succeeding received read commands.

For purposes of discussion, then, the data available to be reduced represents the range change between the first aircraft location seen and all successive aircraft locations seen. The ground receivers each contain a local oscillator which is used as a standard to measure elapsed time and hence range change. Since the ground station oscillator is not at exactly the same frequency as the aircraft reference oscillator and may be drifting at a fixed rate in frequency, the measured data will contain the effects of these discrepencies. The observation equation then contains terms which reflect not only the frequency offset and drift, but also an arbitrary initial range (or phase) term which corresponds to the range from the

ground station to the first aircraft location seen.

The initial range parameter for the j^{th} ground station is designated a_{0j} . The effect of the frequency differences between the aircraft oscillator and the j^{th} ground station oscillator is contained in a term designated a_{1j} . The drift rate between the aircraft and ground station oscillator is designated a_{2j} for the j^{th} station.

The observation equation c_{jk} is then given by

$$G_{jk} = r_{jk} - a_{0j} + a_{1j}t_k + a_{2j}\frac{t_k^2}{2}$$

where

$$r_{jk} = \left(\sum_{m=1}^{3} (q_{mk} - p_{mj})^2\right)^{1/2}$$

 $a_{0,j}$ is the initial range parameter

 $a_{1,i}$ is the frequency offset parameter

 a_{2j} is the frequency drift rate parameter

 t_k is the time between the first and the k^{th} aircraft interrogation command.

1

It is worth note at this point to indicate that in fact the effects of the oscillator offset and drift will be dependent on the time difference between the first aircraft interrogation time seen by a particular ground station and the succeeding interrogations. Thus, a particular ground station might first see the aircraft on the second, third or any later interrogation time rather than the first. It would be possible to include this exact situation in the data reduction only at the expense of a considerable rearrangement of the structure of the matrices involved. In so far as the positions of the ground stations such a reorganization is unnecessary since an arbitrary shift in the zero time point only changes the values of a_{0j} , a_{1j} , and a_{2j} recovered by the data reduction procedure. Therefore, to preserve the matrix structure (without detrimental effect on accuracy) the values of a_{0j} , a_{1j} and a_{2j} will be estimated as though all ground stations saw the first aircraft interrogation (whether or not any of them actually did). The only implication of this procedure is that if the actual values of a_{1j} and a_{2j} are desired (for test purposes perhaps) then

the results of the data reduction procedure will require some additional interpretation beyond a direct readout of the estimated values.

The apriori information about the estimated parameters is contained in a vector Q_e and a covariance matrix W_2^{-1} which contains the estimates of the error in the apriori vector Q_e . The functional to be minimized by a choice of \hat{Q} is then given by

$$F = \left[M - G(Q) \right]^T W_1 \left[M - G(Q) \right] + \left[Q_e - Q \right]^T W_2 \left[Q_e - Q \right],$$

where W_1 is the covariance matrix of measurement error and W_2^{-1} is the covariance matrix of the apriori errors in Q_e . The minimization of the functional F is accomplished by partially differentiating F with respect to each of the parameters being estimated then equating the resultant set of (nonlinear) equations to the zero vector and solving for the value of Q which satisfies these equations. Then

$$\frac{\partial F}{\partial \hat{Q}} = 0 = -A^{T}(Q)W_{1} \left[M - G(Q) \right] - W_{2} \left[Q_{e} - Q \right]$$

where A(Q) is the matrix of partial derivatives of the function G(Q) with respect to the vector Q evaluated at the value of Q. At the solution point the vector Q may be represented as

$$Q = Q_T + \delta Q$$

where Q_T represents the true values of the parameters being estimated. The function $\mathcal{G}(Q)$ is then

$$G(Q) = G(Q_T) + \frac{\partial G}{\partial Q_T} \delta Q = G(Q_T) + A(Q_T) \delta Q$$
.

Substituting this value for G(Q) into the above relationship gives

$$0 = -A^{T}(Q_{T}) W_{1} \left[M - G(Q_{T}) - A(Q) \delta Q \right] - W_{2} (Q_{e} - Q_{T} - \delta Q) .$$

The vector M - $G(Q_T)$ is, by definition of the observational equation, the vector of measurement errors δR . The vector Q_e - Q_T will be defined to be δQ for convenience (it is the vector of errors in the apriori vector Q_e). Making these substitutions and rearranging the equation gives:

$$\left[A^{T}(Q_{T}) \ W_{1} \ A(Q_{T}) + W_{2} \right] \delta Q = A^{T} \ (Q_{T}) \ W_{1} \delta R + W_{2} \delta Q.$$

The solution of this equation for δQ would give the errors in the estimated parameters (i.e., δQ) as a function of the measurement error, δR , and the apriori information errors, $\dot{\delta}Q$. This equation also provides a basis for solving for the value of the vector Q which satisfies the set of nonlinear equations derived above. If δR is interpreted as the current difference vector between the measurements and the current value of the observation equation, and $\dot{\delta}Q$ is the difference vector between the apriori estimate of Q and the current value of Q a recursive method of finding Q can be formulated. Suppose \hat{Q}_i is the present value of Q then

$$\delta R_i \equiv M - G(\hat{Q}_i) ,$$

$$\delta Q_i \equiv Q_e - \hat{Q}_i .$$

Then

$$\left[A^{T}(\hat{Q}_{i}) W_{1} A(\hat{Q}_{i}) + W_{2}\right] \delta Q_{i} = A^{T}(\hat{Q}_{i}) W_{1} \delta R_{i} + W_{2} \delta Q_{i},$$

defines a value for δQ_i which may be used to determine a better estimate of \hat{Q}_i or $\hat{Q}_{i+1} = \hat{Q}_i + \delta Q_i$

The overall procedure then to start with an Aitial estimate of $\hat{Q}_0 = Q_e$ (the apriori information), the two covariance matrices W_1^{-1} and W_2^{-1} , and then iterate the value of the vector \hat{Q}_i until the correction δQ_i is the zero vector.

The matrix of partial derivatives of G(Q) with respect to Q is defined in the previous development to be the matrix A. Because of the dimensions of the matrix A, the requirements for storage of the various matrices involved would exceed the capabilities of most computers considered for field usage. The structure of the matrix allows partitioning so that the sizes of the matrices involved and the computer storage requirements are both reduced. The matrix A can be written as

$$A = \frac{C}{B}$$

where the matrix C contains the partials of G(Q) with respect to the ground station parameters and B contains the partials with respect to the aircraft locations. The vector δQ may then be partitioned into

$$\delta Q = \frac{\delta p}{\delta q}$$

with δp the vector of station parameter corrections and δq the vector of aircraft location corrections. It is further assumed that the covariance matrix W_2^{-1} is of the form

$$w_2^{-1} = \begin{bmatrix} w_p^{-1} & 0 \\ 0 & w_q^{-1} \end{bmatrix}$$

where W_p^{-1} and W_q^{-1} are the covariance matrices of the apriori errors in the ground station and aircraft parameters respectively. This implies that there is no correlation between the apriori errors in ground station parameters and aircraft parameters which is a reasonable assumption. With these definitions the basic equation to be solved can be restated in terms of the separate matrices and vectors relating to the ground and aircraft portions of the problem.

The original equation to be solved for δQ is given by:

$$(A^{T}W_{1}A + W_{2})\delta Q = A^{T}W_{1}\delta R + W_{2}\delta Q$$

so that with

$$A = \begin{bmatrix} \frac{C}{B} \end{bmatrix}; \qquad Q = \begin{bmatrix} \frac{\delta p}{\delta q} \end{bmatrix}; \qquad W_2 = \begin{bmatrix} W_p & 0 \\ 0 & W_q \end{bmatrix}; \qquad \delta \dot{Q} = \begin{bmatrix} \frac{\delta \dot{p}}{\delta \dot{q}} \end{bmatrix}$$

the equation becomes

$$\begin{bmatrix} c^T w_1 c + w_p & c^T w_1 B \\ B^T w_1 c & B^T w_1 B + w_q \end{bmatrix} \begin{bmatrix} \delta p \\ \delta q \end{bmatrix} = \begin{bmatrix} c^T w \\ B^T w_1 \end{bmatrix} \delta R + \begin{bmatrix} w_p \delta \dot{p} \\ w_q \delta \dot{q} \end{bmatrix}$$

The matrix B^T is structured as follows

and

$$B_{i}^{T} = \begin{bmatrix} (q_{1i} - p_{11})/r_{1i} & \dots & (q_{1i} - p_{1J})/r_{Ji} \\ (q_{2i} - p_{21})/r_{1i} & \dots & (q_{2i} - p_{2J})/r_{Ji} \\ (q_{3i} - p_{31})/r_{1i} & \dots & (q_{3i} - p_{3J})/r_{Ji} \end{bmatrix} \times J$$

$$r_{jk} = \left(\sum_{n=1}^{3} (q_{nk} - p_{nj})^{2}\right)^{1/2}$$

 q_{nk} is the n^{th} coordinate of the k^{th} A/C location p_{nj} is the n^{th} coordinate of the j^{th} ground station.

Expanding the matrix equations into two equations gives,

1)
$$(c^T w_1 c + w_p) \delta p + c^T w_1 B \delta q = c^T w_1 \delta R + w_p \delta p = \delta \mathbf{z}_1$$

2)
$$B^T W_1 C \delta p + (B^T W_1 B + W_q) \delta q = B^T W_1 \delta R + W_q \delta q$$
 $\delta q = \delta Z_2$.

Solving the second equation for δq gives

$$\delta_{q} = (B^{T} w_{1} B + w_{q})^{-1} (\delta Z_{2} - B^{T} w_{1} C \delta p).$$

Substituting for δq in equation 1) gives

$$\begin{split} &(c^T w_1 c + w_p) \delta p + c^T w_1 B (B^T w_1 B + w_q)^{-1} \left(\delta Z_2 - B^T w_1 c \delta R \right) = \delta Z_1 \\ & \Big[w_p + c^T w_1 c - c^T w_1 B (B^T w_1 B + w_q)^{-1} B^T w_1 c \Big] \delta p = \delta Z_1 - c^T w_1 B \hat{\delta} Z_2 \\ & \hat{\delta} Z_2 = (B^T w_1 B + w_q)^{-1} \delta Z_2 \ . \end{split}$$

Let the matrix V be defined by

$$V = \left[W_p + c^T w_1 c - c^T w_1 B \left(B^T w_1 V + W_q \right)^{-1} B^T w_1 c \right].$$

Then

$$\delta p = V^{-1}(\delta Z_1 - c^T W_1 B \hat{\delta} Z_2).$$

Substituting back to solve for δq gives

$$\delta q = \hat{\delta} Z_2 - (B^T W_1 B + W_q)^{-1} B^T W_1 C \delta p$$
.

The matrix W_1 is diagonal with entries $1/\sigma^2$ so that the constant value σ^2 can be moved into the constraint matrices W_p and W_q thus:

The vector δp is made up of

$$\begin{bmatrix}
 p_{11} - \hat{p}_{11} \\
 p_{21} - \hat{p}_{21} \\
 p_{31} - \hat{p}_{31}
\end{bmatrix}$$

$$\begin{vmatrix}
 p_{1J} - \hat{p}_{1J} \\
 p_{2J} - \hat{p}_{2J}
\end{vmatrix}$$

$$\begin{vmatrix}
 p_{2J} - \hat{p}_{2J} \\
 a_{0j} - \hat{a}_{0j}
\end{vmatrix}$$

$$\begin{vmatrix}
 a_{1j} - \hat{a}_{1j} \\
 \vdots
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where \hat{x} is the apriori estimate of the parameter * being estimated from the data.

The vector δZ_1 is given by

$$\delta Z_1 = \sigma^2 W_p \delta p + c^T \delta R,$$

vector
$$\delta Z_1$$
 is given by
$$\delta Z_1 = \sigma^2 W_p \dot{\delta} p + c^T \delta R,$$

$$= \sigma^2 W_p \dot{\delta} p + \begin{bmatrix} -c_2^T & \dots & -c_K^T \\ I & & I \\ -T_2^T & \dots & T_K^T \\ -\dot{T}_2^T & \dots & -T_K^T \end{bmatrix} \begin{bmatrix} \delta r_2 \\ \vdots \\ \delta r_K \end{bmatrix}$$

$$= \sigma^{2} \mathbf{W}_{p} \dot{\delta} p + \begin{bmatrix} -\Sigma C_{i}^{T} \delta \mathbf{r}_{i} \\ \Sigma \delta \mathbf{r}_{i} \\ -\Sigma T_{i}^{T} \delta \mathbf{r}_{i} \end{bmatrix} J$$

$$= \sigma^{2} \mathbf{W}_{p} \dot{\delta} p + \begin{bmatrix} -\Sigma C_{i}^{T} \delta \mathbf{r}_{i} \\ -\Sigma T_{i}^{T} \delta \mathbf{r}_{i} \end{bmatrix} J$$

The vector δZ_2 is given by

$$\delta Z_{2i} = -B_{i}^{T} \delta r_{i} + \sigma^{2} W_{q}^{i} \delta_{q}^{i} \quad 3 \times 1 .$$

$$\delta Z_{2i} = (B_{i}^{T} B_{i} + \sigma^{2} W_{q}^{i})^{-1} \delta Z_{2i} \quad 3 \times 1 .$$

$$c^{T}B\hat{\delta}z_{2} = \begin{bmatrix} -c_{2}^{T} & \cdots & -c_{K}^{T} \\ I & & & \\ -T_{2}^{T} & \cdots & & \\ -\hat{T}_{2}^{T} & & & \end{bmatrix} \quad \begin{bmatrix} -B_{2} & & & \\ & \ddots & & \\ & & \ddots & & \\ & & & \\ & & -B_{K} \end{bmatrix} \quad \begin{bmatrix} \hat{\delta}z_{22} \\ \vdots \\ \hat{\delta}z_{2K} \end{bmatrix} ,$$

$$= \begin{bmatrix} \Sigma c_i^T B_i \hat{\delta} Z_{2i} & 3J \\ -\Sigma B_i \hat{\delta} Z_{2i} & J \\ \Sigma T_i^T B_i \hat{\delta} Z_{2i} & J \\ \Sigma \hat{T}_i^T B_i \hat{\delta} Z_{2i} & J \end{bmatrix}$$

Then,

$$\hat{\delta}Z_{1} = \delta Z_{1} - c^{T}B\hat{\delta}Z_{2} = \sigma^{2}W_{p}\hat{\delta}p + \begin{bmatrix} -\Sigma c_{i}^{T}\delta r_{i} - \Sigma c_{i}^{T}B_{i}\hat{\delta}Z_{2i} \\ \Sigma \delta r_{i} + \Sigma B_{i}\hat{\delta}Z_{2i} \\ -\Sigma T_{i}^{T}\delta r_{i} - \Sigma T_{i}^{T}B_{i}\hat{\delta}Z_{2i} \\ -\Sigma T_{i}^{T}\delta r_{i} - \Sigma T_{i}^{T}B_{i}\hat{\delta}Z_{2i} \end{bmatrix},$$

$$= \sigma^{2}W_{p}\delta p + \begin{bmatrix} -\Sigma C_{i}^{T} & (\delta r_{i} + B_{i}\delta Z_{2i}) \\ \Sigma(\delta r_{i} + \Sigma B_{i}\delta Z_{2i}) \\ -\Sigma T_{i}^{T}(\delta r_{i} + B_{i}\delta Z_{2i}) \\ -\Sigma T_{i}^{T}(\delta r_{i} + B_{i}\delta Z_{2i}) \end{bmatrix}$$

$$= \Delta T_{i}^{T}(\delta r_{i} + B_{i}\delta Z_{2i})$$

$$= \sigma^{2} W_{p} \mathring{\delta}p + \begin{bmatrix} -\Sigma C_{i}^{T} \delta Z_{3} \\ \Sigma \delta Z_{3} \\ -\Sigma T_{i}^{T} \delta Z_{3} \end{bmatrix} J$$

$$\begin{bmatrix} \Sigma \delta Z_{3} \\ -\Sigma T_{i}^{T} \delta Z_{3} \end{bmatrix} J$$

$$\delta Z_{3} \equiv \delta r_{i} + B_{i} \mathring{\delta} Z_{2i} \quad J \times 1$$

The vector $\delta z_1 - c^T B \delta z_2$ is required along with δz_2 .

- 2. COMPUTATION PROCEDURE
- 1. Initialize a vector $6J \times 1$ with $\sigma^2 W_p \mathring{\delta}_p (\hat{\delta} Z_1)$
- 2. Initialize a vector $3(k-1) \times 1$ with $\sigma^2 W_{\alpha} \hat{\delta}_{\alpha} (\hat{\delta} Z_{2i})$
- 3. Initialize a matrix to be diagonal $\sigma^2 W_p$ to store the coefficient matrix V
- 4. Start a "do" loop on i = 2, k
- 4.1 form matrix B_i and save $(J \times N)$
- 4.2 form matrix B_i^T $(N \times J)$
- 4.3 product $B_i^T B_i$ $(N \times N)$
- 4.4 add $\sigma^2 W_q^i$ to get $B_i^T B_i + \sigma^2 W_q^i$
- 4.5 invert $(B_i^T B_i + \sigma^2 W_G^i)^{-1}$ and save
- $4.6 \quad \hat{\delta Z}_{2i} = \hat{\delta Z}_{2i} B_{i}^{T} \delta r_{i}$
- 4.7 $\hat{\delta}Z_{2i} = (B_i^T B_i + \sigma^2 W_q^i)^{-1} \hat{\delta}Z_{2i}$
- $4.8 \quad \delta Z_3 = \delta r_i + B_i \delta Z_{2i}$
- 4.9 $\hat{\delta}Z_1 = \hat{\delta}Z_1 + [-C_i^T \delta Z_3, \delta Z_3, -T_i^T \delta Z_3, -\tilde{T}_i^T \delta Z_3]^T$
- 4.10 product $B_{i}(B_{i}^{T}B_{i} + \sigma^{2}W_{q}^{i})^{-1}$ $(J \times N)$
- 4.11 product $B_{i}(B_{i}^{T}B_{i} + \sigma^{2}W_{q}^{i})^{-1}B_{i}^{T}$ $(J \times J)$
- 4.12 form $U_i = I B_i (B_i^T B_i + \sigma^2 W_q^i)^{-1} B_i^T (J \times J)$
- 4.13 form ΣU; *
- 4.14 form $-\Sigma T_i^T U_i$
- 4.15 form $-\Sigma \dot{T}_i U_i$ *
- 4.16 form $+\Sigma T_i^T U_i T_i$ *
- 4.17 form $\Sigma \dot{T}_i^T U_i \dot{T}_i$ *
- 4.18 form $\Sigma T_{i}^{T} U_{i} \dot{T}_{i}$ * $(J \times J)$
- 4.19 form $C_i^T U_i$ * (3J × J)
- 4.20 form $-\Sigma C_i^T U_i$ * (3J × J)

4.21 form
$$\Sigma C_i^T U_i T_i$$
 (3J × J)

4.22 form
$$\Sigma C_i^T U_i \dot{T}_i$$
 * (3J × J)

4.23 form
$$\Sigma C_{i}^{T} U_{i} C_{i}$$
 * (3 $J \times 3J$)

4.24 form
$$\Sigma C_{i}^{T}U_{i}C_{i}$$
 * (3J ×3J)

* indicates that individual matrices are formed by adding to proper locations in matrix V initialized above.

4.30 end of do loop on i

5. Invert matrix
$$V \rightarrow V^{-1}$$
 (6J × 6J)

6. correction vector
$$\delta_p = V^{-1} \hat{\delta} Z_1$$
 (6*J* × 1)

7. start do loop on
$$i = 2, K$$

7.1 form
$$B_i$$
 and save

7.2 form
$$B_{i}^{T}$$

7.3 product
$$B_{i}^{T}B_{i}$$

7.4 sum
$$B_i^T B_i + \sigma^2 W_q^i$$

7.5 invert
$$(B_i^T B_i + \sigma^2 W_q^i)^{-1}$$

7.6 form vector
$$[-C_i \ I \ T_i \ \dot{T}_i]$$
 δ_p $(J \times 1)$

7.7 product
$$-B_{i}^{T} \times \text{vector} \rightarrow \text{new vector } 3 \times 1$$

7.8 product
$$(B_i^T B_i + \sigma^2 w_q^i)^{-1} \times \text{new vector } 3 \times 1$$

7.9
$$\delta q_i = \hat{\delta} Z_{2i}$$
 - last vector 3×1

7.10 end do loop on i

8. form new estimate of station vector =
$$P - \delta_p$$

9. form new estimate of aircraft vector
$$Q = Q - \delta_q$$

3. PROVISION FOR LOST DATA

In the LRPDS problem it is possible that during the course of the flight terrain or aircraft maneuvers will shadow transmission between the aircraft and any of the ground stations. This will result in loss of range change measurements during times when the ground station is shadowed. Since the data loss may occur at different times for different stations it is necessary to make provision for an arbitrary loss of data for each station at each aircraft

sampling time. The method of handling the loss of data must satisfy three criteria: 1) The method should allow the maximum utilization of the data collected so as to maintain the quality of positioning. 2) The method should not destroy the highly structured form of matrices involved so that full advantage of the structure can be taken in the computational procedure. 3) It is also necessary to retain the ability to provide a figure of merit for the resulting station locations determined by the systems which reflects the effects of the lost data.

The approach taken to provide for lost data can best be visualized by a simplified example. Suppose that a linear least squares estimate is required of the n dimensional vector X from m measurements which constitute the vector Z. The observation equations constitute the rows of a matrix H where dimensions are $m \times n$. The matrix equation relating X and Z is thus

HX = Z.

The solution vector \hat{X} then satisfies the normal equations

$$H^T H \hat{\mathbf{X}} = H^T Z.$$

If in the measurement procedure some z_k (or set of z_k) is lost or considered unacceptable there are two choices of how to handle the data reduction problem. First, the row dimension of the matrix H may be appropriately decreased and the measurements deleted from the vector Z. Second, a zero row vector may be inserted into H at each location of missing data and a zero inserted in Z corresponding to the missing data points.

The second approach has the virtue of not disrupting any of the structure of H so that a fixed data reduction procedure will still accomplish the desired result. In order to accomplish this deletion of rows and data points in an organized fashion define an $m \times m$ diagonal matrix S which has 1 or 0 entries as the particular measurement is present or missing. Then the relationship between X and Z becomes

SHX = SZ .

The solution \hat{X} then satisfies the equation

I is $J \times J$ identity matrix

 T_i is $J \propto J$ diagonal matrix with entries t_i

 t_i is $J \times J$ diagonal with entries $t_i^2/2$

The vectors required are given by:

$$\delta z_1 = c^T \delta R + \sigma^2 w_p \delta p$$

$$\delta Z_2 = B^T \delta R + \sigma^2 W_a \delta_q$$

$$\hat{\delta} z_2 = (B^T B + \sigma^2 W_q)^{-1} \delta z_2$$

$$\delta p = v^{-1}(\delta z_1 - c^T B \delta z_2)$$

$$\delta q = \hat{\delta} z_2 - (B^T B + \sigma^2 W_q)^{-1} B^T C \delta p \quad \bullet.$$

The vector δR may be partitioned into K-1 vectors each J in size,

$$\delta R = \begin{bmatrix} \delta r_2 \\ \vdots \\ \delta r_k \end{bmatrix} J(K-1) \times 1 \qquad \delta r_i \equiv \begin{bmatrix} \delta r_{1i} \\ \delta r_{2i} \\ \vdots \\ \delta r_{Ji} \end{bmatrix}$$
where the results of the second section is a second second

$$\delta r_{i} \equiv \begin{bmatrix} \delta r_{1i} \\ \delta r_{2i} \\ \vdots \\ \delta r_{Ji} \end{bmatrix} J \times$$

The vector $\delta q = \left[\delta q_{12}\right]$

$$V = \left[\sigma^2 W_p + c^T \left[I_- - B \left(B^T B + \sigma^2 W_q \right)^{-1} B^T \right] c \right]$$

$$\delta p = V^{-1} (\delta Z_1 - c^T B \hat{\delta} Z_2)$$

and

$$\delta p = \hat{\delta} Z_2 - (\mathbf{g}^T B + \sigma_j^2 \mathbf{w}_q)^{-1} B^T C \delta p ,$$

with

$$\delta Z_1 = c^T \delta R + \sigma^2 w_p \delta p$$

$$\delta Z_2 = B^T \delta R + \sigma^2 w_q \delta q$$

$$\hat{\delta} Z_2 = (B^T B + \sigma^2 w_q)^{-1} \delta Z_2$$

The matrix V which must be constructed is defined as

$$V = c^T \left[I - B (B^T_B + \sigma^2 W_q)^{-1} B^T \right] C + \sigma^2 W_p.$$

Since ${\it B}$ is block diagonal and $\sigma^2 {\it W}_q$ is diagonal

where $U_i = I - B_i (B_i^T + \sigma^2 W_q^i)^{-1} B_i^T$.

Then the symmetric matrix V is given by

$$V = \begin{bmatrix} \sigma^2 w_P^S + \sum_{i=1}^{K} C_{i}^T U_{i} C_{i} - \sum_{i=2}^{K} C_{i}^T U_{i} & \sum_{i=2}^{K} C_{i}^T U_{i} T_{i} & \sum_{i=2}^{K} C_{i}^T U_{i} T_{i} \\ \sum_{i=2}^{K} C_{i}^T U_{i} T_{i} & -\sum_{i=2}^{K} C_{i}^T U_{i} T_{i} \\ \sum_{i=2}^{K} C_{i}^T U_{i} T_{i} + \sigma^2 w_p^a & \sum_{i=2}^{K} C_{i}^T U_{i} T_{i} \end{bmatrix}$$

Where W_p^S is the diagonal matrix of station location constraints $\Sigma T_i^T U_i T + \sigma^2 W_p^b$

 W_{p}^{RO} is the diagonal initial range constraints

 W_p^a is the freq. offset constraint

 w_n^b is the freq. drift constraint

 $[-(q_{1i} - p_{11})/r_{1i}]$

The matrix c^T is given by

$$c^{T} = \begin{bmatrix} -c_{2}^{T} & -c_{3}^{T} & \dots & -c_{K}^{T} \\ I & I & I \\ -T_{2}^{T} & -T_{3}^{T} & \dots & -T_{K}^{T} \\ -\mathring{T}_{2}^{T} & -T_{3}^{T} & \dots & -\mathring{T}_{K}^{T} \end{bmatrix}$$

$$c_{i}^{T} = \begin{bmatrix} -(q_{2i} - p_{21})/r_{1i} \\ -(q_{3i} - p_{31})/r_{1i} \\ -(q_{1i} - p_{12})/r_{2i} \\ -(q_{2i} - p_{22})/r_{2i} \\ -(q_{3i} - p_{32})/r_{2i} \end{bmatrix}$$

$$\begin{array}{cccc}
 & -(q_{1i} - p_{1J})/r_{Ji} \\
 & -(q_{2i} - p_{2J})/r_{Ji} \\
 & -(q_{3i} - p_{3J})/r_{Ji}
\end{array}$$
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$$\begin{array}{cccc}
 & -(q_{3i} - p_{3J})/r_{Ji} \\
 & -(q_{3i} - p_{3J})/r_{Ji}
\end{array}$$

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$$H^T S^T S H \hat{X} = H^T S^T S Z$$
.

Because S is diagonal and contains only ones and zeros

$$S^TS = S$$

so that,

$$H^T S H \hat{X} = H^T S Z$$

From this simplified example it is evident that the way to include provision for lost data points is to carry the effects of the matrix S through the entire data reduction procedure and delete those entries which would be multiplied by the zero entries in S.

To relate the method of handling lost data directly to the LRPDS problem the development of the equations presented previously can be modified by replacing the matrices C and B with matrices SC and SB. The δR vector is replaced with a vector $S\delta R$. The equations to be solved within the iterative portion of the solution method may then be restated as:

$$\begin{bmatrix} c^T s w_1 s c + w_p & c^T s w_1 s B \\ B^T s w_1 s c & B^T s w_1 s B + w_q \end{bmatrix} \begin{bmatrix} \delta_p \\ \delta_q \end{bmatrix} \begin{bmatrix} c^T s w_1 s \\ B^T s w_1 s \end{bmatrix} \qquad \delta_R + \begin{bmatrix} w_p \dot{\delta}_p \\ w_q \dot{\delta}_q \end{bmatrix}$$

Where all of the symbols are as previously defined.

The primary influence of the inclusion of the lost data matrix S appears in the expression for the matrix V which is the coefficient matrix in the set of normal equations for the δ_n vector.

The matrix V now becomes $\begin{cases}
\sigma^2 w_p^S + \sum_{i=1}^K \hat{v}_i c_i & -\sum_{i=1}^T \hat{v}_i & \sum_{i=1}^T \hat{v}_i T_i & \sum_{i=1}^T \hat{v}_i \hat{T}_i & \sum_{i=1}^T \hat{$

Where $\dot{v}_i \equiv S_i \left[I - B_i^T S_i (B_i^T S_i B_i + \sigma^2 W_q^i)^{-1} S_i B_i \right] S_i$ S_i is the $i^{\text{th}} J \times J$ block (along the diagonal) of S_i , the lost data matrix.

Another impact lost data has on the overall reduction problem is that if the number of ground stations visible from each aircraft location falls below some minimum value the solution for that aircraft location will either be impossible or so weak as to not be useful. If this happens then that aircraft location (or set of locations) must be excluded from the solution.

The minimum number of visible ground stations allowable from each aircraft location is a function of how many coordinates of the aircraft position are being estimated at once. From geometric consideration, it is evident that for two coordinates being estimated (x, y) then there must be observation available from three or more non-colinear ground stations to resolve the possible ambiguity in the solution. In a similar way, if three coordinates (x, y, z) are being estimated, then observation from four or more non-coplanar stations must be available. Although the use of four observations does not guarantee that the stations observed are not coplanar, it is certain that if only three stations are used, they will be coplanar (since three points uniquely define a plane). Without these constraints on the number of stations visible it is possible for the iterative solution to drive any aircraft point not having at least the minimum to an incorrect solution point corresponding to the wrong member of an ambiguous pair of solutions.

4. REQUIREMENTS FOR SELECTABLE ESTIMATION OF PARAMETERS

The formulation of the data reduction procedure up to this point has assumed that all of the parameters mentioned[i.e. 3J station locations, J initial ranges, J frequency offsets, J frequency drifts, and 3 (k-1) aircraft location parameters] are required to be estimated. Although this is true in the final stages of the adjustment, it is not true in the first few iterations to bring the parameters of interest into the range for final adjustment. The total data reduction program must therefore have provisions for selecting those parameters which are to be estimated at each stage of the data reduction procedure.

It is necessary to restrict the estimation to aircraft x, y only for the first few iterations in order to bring the relatively unknown flight path parameters close enough to the true values to perform the full adjustment on all parameters. This means that for the aircraft portion of the problem only two position parameters are to be estimated rather than three. In a similar way, the ground station parameters to be estimated will vary depending on the degree of certainty of the solution. It, therefore, becomes necessary to provide for a flexible selection of the parameters to be estimated for both the aircraft locations and the ground station parameters.

AIRCRAFT PARAMETER SELECTION

For the aircraft locations there are only three choices to be considered:

- 1) Estimate aircraft x, y and z
- 2) Estimate aircraft x, y
- 3) Do not estimate aircraft locations.

GROUND STATION PARAMETER SELECTION

For the ground station parameters the number of choices is more complex.

Ground Station Position Coordinates

- 1. Estimate all ground station position parameters x, y, z
- 2. Estimate ground stations x, y only
- 3. Do not estimate ground station positions

Ground Station Initial Range - a_{oj}

The estimation of the a_{oj} term for each ground station is required for all circumstances.

Ground Station Frequency Offset - $a_{1,j}$

The ground station frequency offset, a_{1j} , may or may not be required depending on the level of accuracy required at a given stage of the data reduction.

Ground Station Frequency Drift Rate - $a_{2,j}$

The frequency drift rate, a_{2j} , must be selectable.

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5. DATA REDUCTION FLOW DIAGRAM

The overall requirements for the data reduction and the equations to be mechanized have been established by the preceding discussion. The outline of the data reduction procedure may now be formulated to include all of the provisions required.

In order to derive the flow diagram for the computation the following notation is used:

J - number of ground stations being processed

NG - number of ground station position coordinates to be estimated (2 or 3) (x, y or x, y, z)

IGC - control parameter (1 or 0)

IGC = 1 enables the estimation of the ground station positions

IGC = 0 disables the estimation of ground station position

$$(p_{mj}; m = 1, NG; j = 1, J)$$

IA1 - control parameter (1 or 0)

IA1 = 1 enables the estimation of ground station frequency offset

$$(a_{1j}; j = 1, J)$$

IA2 - control parameter

IA2 = 1 enables the estimation of ground station frequency drift rate. $(a_{2j}; j = 1, J)$

K - total number of aircraft locations used

NA - number of aircraft position coordinates estimated (2 or 3) (x, y or x, y, z)

IAC - control parameter (1 or 0)

IAC = 1 enables the estimation of the aircraft location

IK(i) - control parameter

IK(i) = 1 enables the estimation of the ith aircraft location

IK(i) is set to zero if the number of ground stations visible fails to satisfy the necessary criterion.

NSTA - minimum number of stations required to be visible from each aircraft location

NSTA = NA + 1

- IDATA (j, i) Control variable (1 or 0) which defines the diagonal elements of the lost data matrix S. The existence of a 1 at location j, i of the IDATA (j, i) control matrix denotes that the jth station was visible from the ith aircraft location and conversely if a zero exists.
- IACS, IGCS Control parameters (1 or 0)

 IACS = 1 or IGCS = 1 denotes that one or more aircraft locations or ground station parameters have not satisfied the convergence criterion and hence another iteration of the problem is required.

 When all parameters have satisfied the convergence criteria then IACS and IGCS will be zero.
- J1, J3, J4, J5 indices of the location of various parts of the matrix V.

 The symmetric matrix V is organized in block form as shown below

77/-2 -25	317		31(72 75)
V(J1, J1)	V(J1, J3)	V(J1, J4)	. V(J1, J5)
NG•J × NG•J	NG•J × J	NG•J:×:J:	NG•J×J
	V(J3, J3)	V(J3, J4)	V(J3, J5)
	J×J	J×J	J.×.J.;;;;
		V(J4, J4)	V(J4, J5)
		J×J	J:×:J:
			V(J5, J5)
		111 == 1	J×J·

The indices shown refer to the first row and column (upper, left hand corner) of each sub-matrix.

In a similar way the vector $\hat{\delta}Z_1$ is denoted by

$$\hat{\delta}Z_1(J1)$$
 NG•J ×·1

$$\hat{\delta}Z_1(J3)$$
 J × 1

$$\hat{\delta Z}_{1}(J3) \qquad J \times 1$$

$$\hat{\delta Z}_{1}(J4) \qquad J \times 1$$

$$\hat{\delta}Z_1(J5)$$
 $J \times 1$

to distinguish the various component parts of the vector.

In general

J1 - defines the location containing elements of the matrix (or vector) related to ground station position. (pmi)

J3 - defines the location related to initial range estimation. (a_{0i})

J4 - defines the location related to frequency offset. (a1i)

J5 - defines the location related to frequency drift rate (a_{2j})

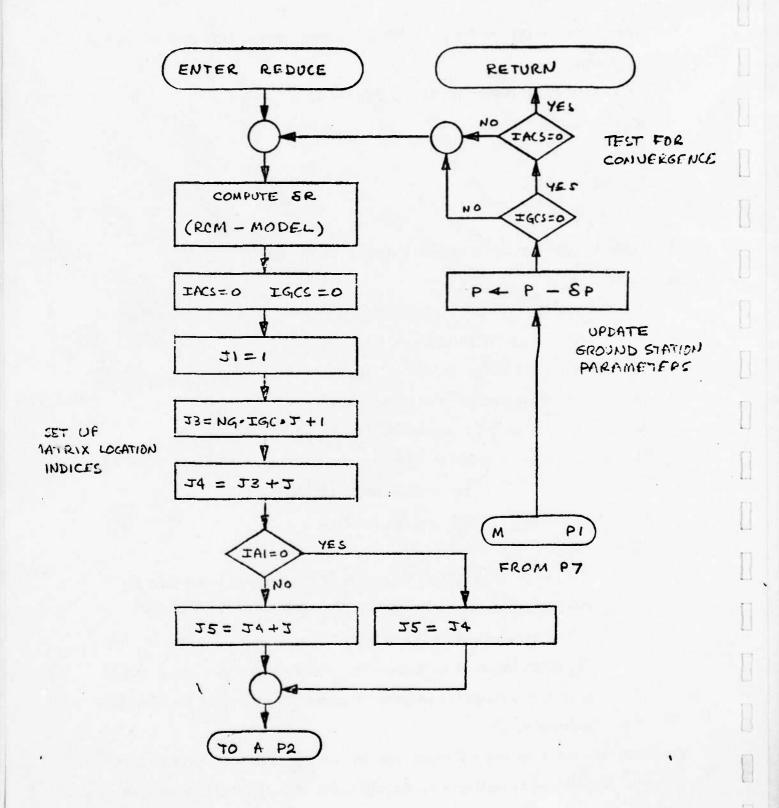
S1, S2, S3, S4, S6 - Refer to temporary matrix storage locations required in the evaluation of the matrix V.

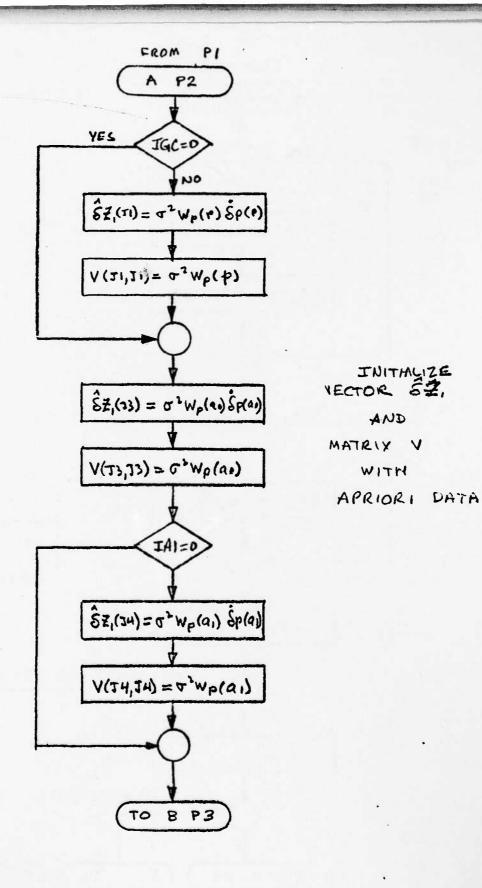
DRP - is a temporary vector storage location

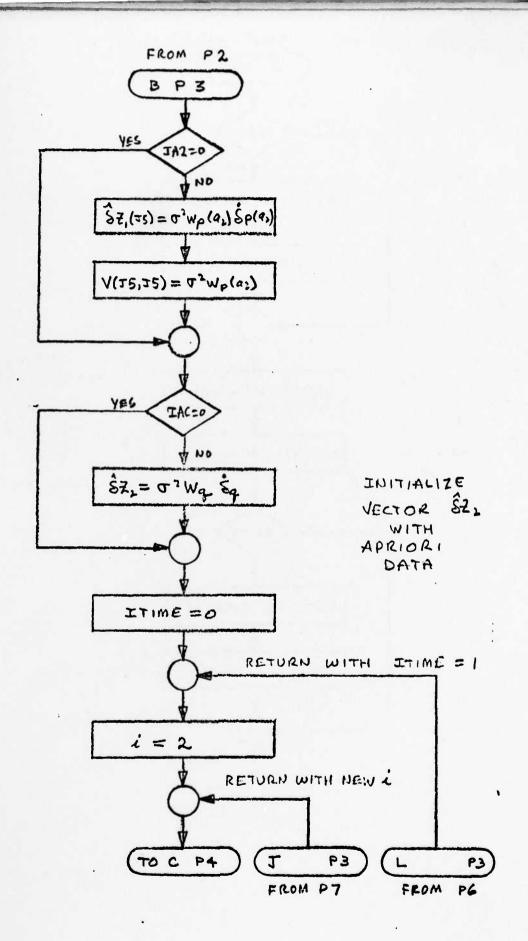
ITIME - control variable (1 or 0)

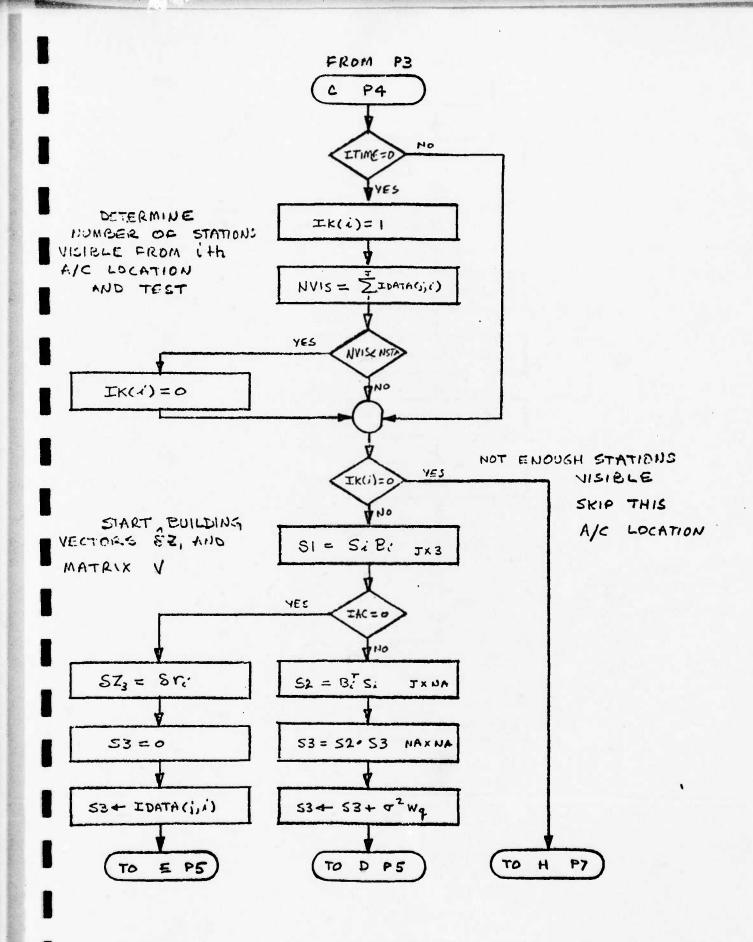
The use of ITIME allows a portion of the program to be used for two different purposes. When ITIME = 0 the path through the computation procedure yields the matrix V and the vectors $\hat{\delta} Z_1$ and δZ_2 which are used to compute δp . ITIME is set to 1 and a second pass made through the program to compute the aircraft location correction oq.

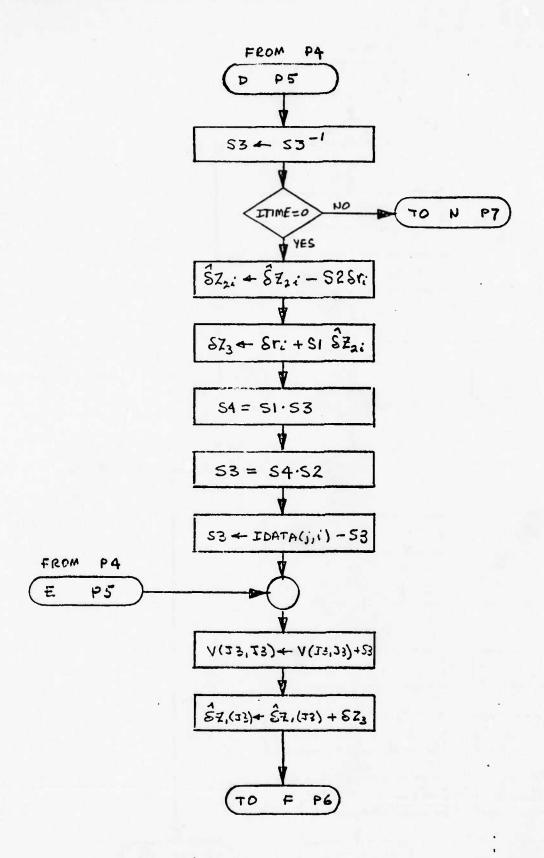
The notation A+A + B means that the new value of the variable A is Notation: determined by adding B to the old value of A. In most cases this operation could be written as $A_i = A_{i-1} + B_i$, but in order to reduce the notational requirements the form listed above was used.

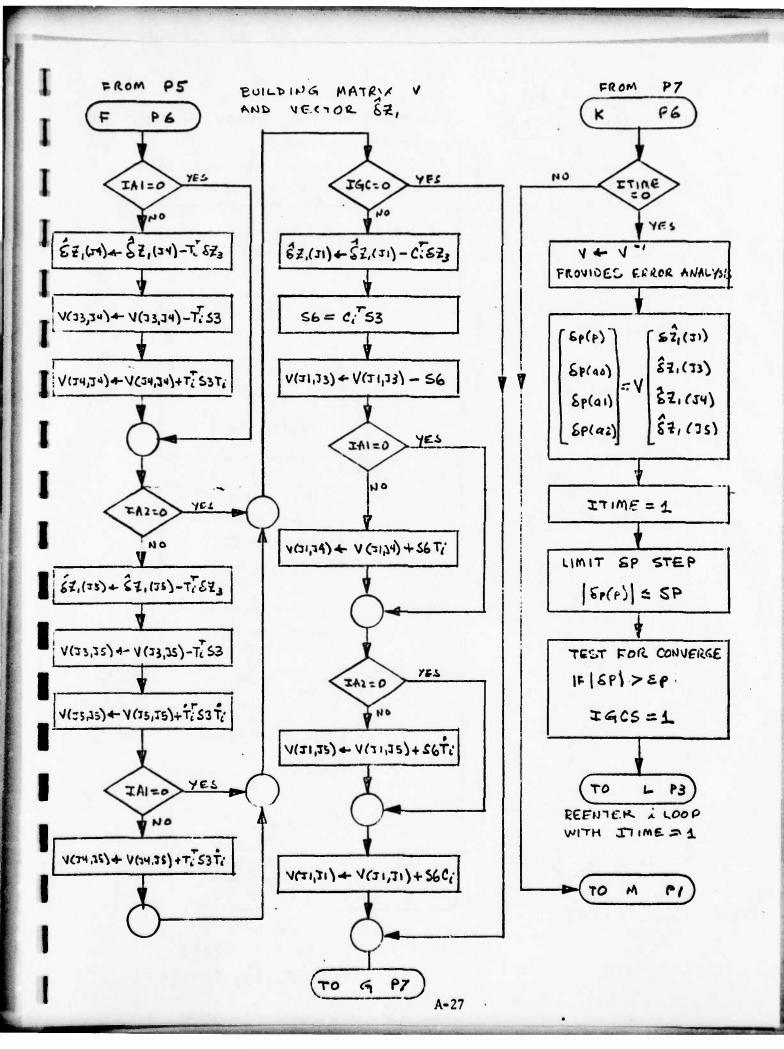


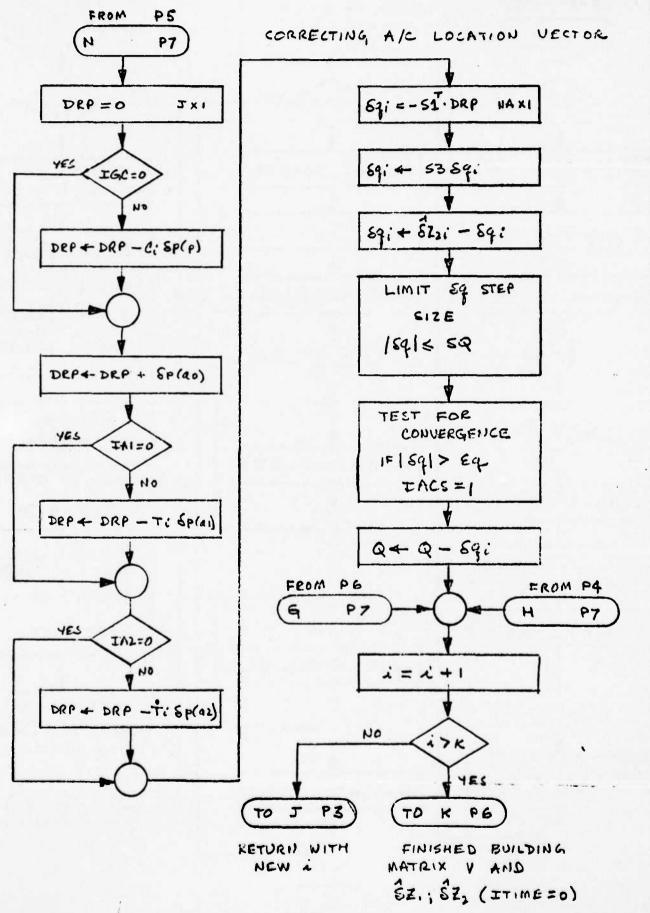












APPENDIX B

COORDINATE CONVERSION CALCULATIONS

1.0 INTRODUCTION

The requirements for the LRPDS program state that positional data input to and output from the computer terminal be in either Universal Transverse Mercator (UTM) or Geodetic Latitude and Longitude Coordinates (LAT-LONG). The nature of the data reduction problem is such that it is highly desirable to utilize a simple local X, Y, Z coordinate system thus avoiding many trig function calculations. The most direct way to approach this coordinate conversion problem is to convert all coordinates to lat-long and then from lat-long to the coordinate system desired. This method also allows for easy solution to the adjacent zone problem in overlap regions since conversion to Easting and Northing in each zone can be made from the lat-long position. Thus, four routines are required; namely, LAT-LONG to UTM, UTM to LAT-LONG, LAT-LONG to LOCAL, LOCAL to LAT-LONG.

2.0 THE SPHEROID

The accepted shape of the earth for mapping purposes is a spheroid generated by the revolution of an ellipse as shown in Figure 1.

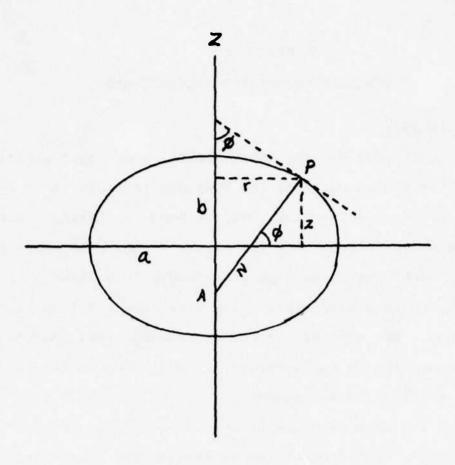


Figure 1. Meridian Ellipse of the Spheroid

In Figure 1, AP = N is the normal to the meridian ellipse at P(r, z). The semi-major axis is a and the geodetic latitude angle is ϕ . The equation for the ellipse is

$$r^2(1 - \epsilon^2) + z^2 - a^2(1 - \epsilon^2)$$
 (1)

where

$$\frac{b^2}{a^2} - (1 - \epsilon^2) \tag{2}$$

and € is the eccentricity, b is the semi minor axis of the ellipse. The spheroid specifications are usually given as the dimension of a and the inverse flattening 1/f. This factor is related to the other parameters as

$$\frac{1}{f} = \frac{a}{a - b} \tag{3}$$

or

$$b = a(1 - f) \tag{4}$$

and

$$\epsilon^2 = f(2, -f) \tag{5}$$

The list of spheroids in common usage are listed in Table 1.

Since the slope of the normal at P is the negative reciprocal of the slope of the tangent.

$$\tan \phi = -\frac{d\mathbf{r}}{dz} = \frac{z}{\mathbf{r}(1-\epsilon^2)} \tag{6}$$

then

$$z = r(1 - \epsilon^2) \tan \phi = N(1 - \epsilon^2) \sin \phi \tag{7}$$

Substituting the value of z in terms of r we have

$$r = \frac{a \cos \phi}{\sqrt{1 - \epsilon^2 \sin^2 \phi}} = N \cos \phi \tag{8}$$

then

$$N = \frac{a}{\sqrt{1 - \epsilon^2 \sin^2 \phi}} \tag{9}$$

Name	Where Used	a (meters)	1/f
Airy	United Kingdom	6,377,563.396	299.324964
Australian National (IAU)	Australia	6,378,160.0	298.25
Bessel	East & Southeast Asia	6,377,397.155	299.152813
Clark 1858	Australia	6,378,293.645	294.26
Clark 1866	North America and Philippines	6,378,206.4	294.978698
Clark 1880	South Africa	6,378,249.145	293.465
Everest *	India	6,377,276.3452	300.8017
Fisher *	Southeast Asia	6,378,155.0	298.3
International	Other Areas	6,378,388.0	297.0
Krasovskii 1940	USSR and Eastern Europe	6,378,245.0	298.3

^{*} The Fisher is tentatively scheduled to replace the Everest.

Table 1. Spheroid Parameters in Terms of Semi-Major Axis (a) and Inverse Flattening (1/f)

i

The radius of curvature of the meridian ellipse is given by

$$R = \frac{a(1 - \epsilon^2)}{(1 - \epsilon^2 \sin^2 \phi)^{3/2}}$$
 (10)

In Figure 2 the ellipse has been revolved about its minor axis through an angle λ with the point P moving to P¹. In the X, Y, Z coordinate system, we have

$$y = r \sin \lambda = N \cos \phi \sin \lambda$$
 (11)

$$x = r \cos \lambda = N \cos \phi \cos \lambda \tag{12}$$

$$z = N (1 - \epsilon^2) \sin \phi \tag{13}$$

$$\frac{x^2 + y^2}{a^2} + \frac{z^2}{b^2} = 1 \tag{14}$$

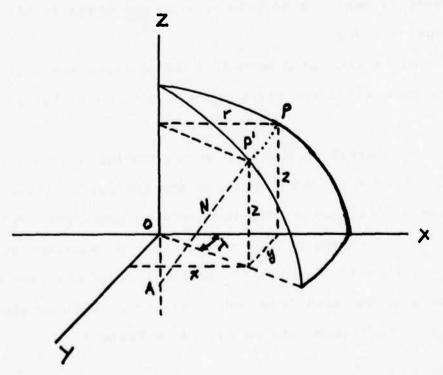


Figure 2. Generation of Spheroid

3.0 THE UNIVERSAL TRANSVERSE MERCATOR GRID AND PROJECTION (UTM)

The transverse Mercator projection is a conformal projection in that the angles measured on the projection or computed from the grid coordinates closely approximate their true values as well as the local scale factor at any point is the same in all directions. If we consider that a Mercator projection is similar to a projection upon a cylinder encasing the earth, the orientation of the cylinder axis for a transverse projection would be in the equatorial plane with the cylinder tangent to the earth at the central meridian of the map projection.

There are 60 transverse Mercator zones each 6° in width extending north to 84° and south to 80°. Zone number one lies between 180° and 174° west longitude. The zones are numbered consecutively from west to east. A 50 mile overlap provision is provided for at each zone boundry.

A scale factor of 0.9996 introduced along the central meridian of each zone gives the effect of a secant condition in the geometric sense.

The zone contains a metric grid superimposed upon it with a 500,000 meter false Easting along the central meridian, a zero meter Northing at the equator for the Northern Hemisphere and a 10,000,000 meter false Northing at the equator for the Southern Hemisphere.

The ellipsoid on which the projection and grid are based depends upon the area involved. The Clarke 1866 is used in North America. Other areas are as listed in Table 1.

3.1 UTM GRID FROM LAT-LONG COORDINATES

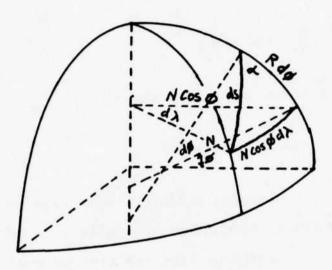


Figure 3. The Linear Element of the Spheroid is Obtained from A Differential Right Triangle

The transverse Mercator projection is a conformal mapping of the spheroid onto a plane such that a rhumb line intersects each meridian at a constant angle. From Figure 3, we have

$$\tan \alpha = \frac{N \cos \phi \, d\lambda}{r d \phi} \tag{15}$$

or

$$d\lambda = \tan \alpha \cdot \frac{R}{N} \sec \phi d\phi$$
 (16)

Setting α equal to a constant the integral curves are

$$\lambda - \lambda_0 = \tau \tan \alpha \tag{17}$$

where au, the isometric latitude, is given by

$$\tau = \int_{0}^{\phi} \frac{R}{N} \sec \phi \ d\phi \tag{18}$$

now in mapping the z plane onto the w plane,

$$W = X + iy = f(Z) = f(\lambda + i \tau)$$
 (19)

The requirement for a transverse Mercator projection is that the scale shall be true along the central map meridian. Hence when $\lambda = 0$ we must have x = 0 and from (18) and (19) we must then have

$$iy = f(i\tau) = i S_{\phi}$$
 (20)

where \mathbf{s}_{ϕ} is the arc length along the elliptic meridian of the spheroid from the Equator to latitude ϕ .

$$S_{\phi} = \int_{0}^{\phi} Rd\phi \qquad (21)$$

and from (18) we have

$$Rd \phi = N \cos \phi d \tau \tag{22}$$

So that

$$S_{\phi} = \int_{0}^{\phi} N \cos \phi \, d\tau = f(\tau)$$
 (23)

If we expand $x + iy = f(\lambda + i\tau)$ about the point $z = i\tau$ we obtain

$$x + iy = f(\lambda + i\tau) = f(i\tau) + \lambda f'(i\tau) + \frac{\lambda^2}{2!} f''(i\tau)$$

$$+ \frac{\lambda^3}{3!} f''' (i\tau) + \cdots$$

$$+ \frac{\lambda^{m'}}{m!} f^{R}(i\tau) + \cdots + \frac{\lambda^8}{8!} f^{V^{iii}}(i\tau) + \cdots$$
(24)

now from (20) and (23) it is seen that

$$f(i\tau) = iS_{\dot{0}} = if(\tau) \tag{25}$$

differentiating this expression and substituting into (24) we have

$$x + iy = if(\tau) + \lambda f'(\tau) - \frac{\lambda^2}{2!} if''(\tau) - \frac{\lambda^3}{3!} f'''(\tau)$$

$$+ \frac{\lambda^4}{4!} if^{iv}(\tau) \cdots \cdots$$

$$+ \frac{\lambda^8}{8!} if^{viii}(\tau) + \cdots \cdots$$
(26)

equating real and imaginary parts

$$x = \lambda f'(\tau) - \frac{\lambda^{3}}{3!} f'''(\tau) + \frac{\lambda^{5}}{5!} f^{V}(\tau) - \frac{\lambda^{7}}{7!} f^{Vii}(\tau) + \cdots$$

$$y = f(\tau) - \frac{\lambda^{2}}{2!} f''(\tau) + \frac{\lambda^{4}}{4!} f^{iV}(\tau) - \frac{\lambda^{6}}{6!} f^{Vi}(\tau) + \frac{\lambda^{8}}{8!} f^{Viii}(\tau)$$

$$+ \cdots$$

Using the following derivatives and trig identities:

$$N' = (N - R) \tan \phi$$

$$R' = 3 - \frac{R}{N} (N - R) \tan \phi$$

$$\left(\frac{N}{R}\right)' = -\frac{2(N-R)}{R} \tan \phi$$

$$\frac{d\phi}{d\tau} = \frac{N}{R} \cos \phi$$

$$(N \cos \phi)' = -R \sin \phi$$

$$(N \sin \phi)' = Sec \phi (N - R \sin^2 \phi) = (R \cos \phi)/(1 - \epsilon^2)$$

$$2 \sin n \phi \cos \phi = \sin (n + 1) \phi + \sin (n - 1) \phi$$

$$2 \cos n \phi \cos \phi = \cos (n+1) \phi + \cos (n-1) \phi$$

$$2 \cos n \phi \sin \phi = \sin (n + 1) \phi - \sin (n - 1) \phi$$

2 sin n
$$\phi$$
 sin ϕ = cos (n - 1) ϕ - cos (n + 1) ϕ (28)

Setting $N/R = \sigma$ we have,

$$f'(\tau) = N \cos \phi$$

f"
$$(\tau) = (N^1 \cos \phi - N \sin \phi) \frac{d\phi}{d\tau} = -\frac{N}{2} \sin 2\phi$$

$$f'''(\tau) = -\frac{N}{4} \left[(3\sigma - 1) \cos \phi + (\sigma + 1) \cos 3\phi \right]$$

$$f'''(\tau) = \frac{N}{8} \left[2(-1 + \sigma + 4\sigma^2) \sin 2\phi + (1 + \sigma + 4\sigma^2) \sin 4\phi \right]$$

The same

$$f^{V} = \frac{N}{16}$$

$$\begin{cases} 2(1 - 2\sigma + 13\sigma^{2} - 4\sigma^{3}) \cos \phi \\ + (-3 + 2\sigma - 3\sigma^{2} + 44\sigma^{3}) \cos 3\phi \\ + (1 + 2\sigma - 7\sigma^{2} + 28\sigma^{3}) \cos 5\phi \end{cases}$$

$$(5 - 6\sigma - 91\sigma^{2} + 364\sigma^{3} - 136\sigma^{4}) \sin 2\phi \\ + 4(-1 + \sigma^{2} - 28\sigma^{3} + 88\sigma^{4}) \sin 4\phi \\ + (1 + 2\sigma + 33\sigma^{2} - 196\sigma^{3} + 280\sigma^{4}) \sin 6\phi \end{cases}$$

$$\begin{cases} (-5 + 9\sigma - 279\sigma^{2} + 1911\sigma^{3} - 2044\sigma^{4} + 680\sigma^{5}) \cos \phi \\ + (9 - 9\sigma + 267\sigma^{2} - 2831\sigma^{3} + 6076\sigma^{4} - 2280\sigma^{5}) \cos 5\phi \\ + (-5 - 3\sigma + 97\sigma^{2} - 293\sigma^{3} - 1708\sigma^{4} + 3592\sigma^{5}) \cos 5\phi \\ + (1 + 3\sigma - 85\sigma^{2} + 1277\sigma^{3} - 4116\sigma^{4} + 3640\sigma^{5}) \cos 7\phi \end{cases}$$

$$\begin{cases} 2(-7 + 9\sigma + 819\sigma^{2} - 12413\tau^{3} + 36984\sigma^{4} - 3640\sigma^{5}) \cos 7\phi \\ + 2(7 - 3\sigma - 279\sigma^{2} + 7243\sigma^{3} - 38568\sigma^{4} + 58512\sigma^{5} - 20864\sigma^{6}) \sin 2\phi \\ + 2(7 - 3\sigma - 279\sigma^{2} + 7243\sigma^{3} - 38568\sigma^{4} + 58512\sigma^{5} - 20864\sigma^{6}) \sin 4\phi \\ + 6(-1 - \sigma - 91\sigma^{2} + 1381\sigma^{3} - 2872\sigma^{4} - 3344\sigma^{5} + 7168\sigma^{6}) \sin 6\phi \\ + (1 + 3\sigma + 279\sigma^{2} - 7235\sigma^{3} + 44136\sigma^{4} - 3640\sigma^{5}) \cos 7\phi \end{cases}$$

(29)

 $90384\sigma^5 + 58240\sigma^6$) sin 8 ϕ

Substituting (29) into (27) we have

$$\frac{X}{N} = \lambda \cos \phi + \frac{\lambda^3}{24} \left[(3\sigma - 1) \cos \phi + (\sigma + 1) \cos 3\phi \right]$$

$$+ \frac{\lambda^5}{1920} \left[2(1 - 2\sigma + 13\sigma^2 - 4\sigma^3) \cos \phi + (-3 + 2\sigma - 3\sigma^2 + 44\sigma^3) \cos 3\phi + (1 + 2\sigma - 7\sigma^2 + 28\sigma^3) \cos 5\phi \right]$$

$$\frac{Y}{N} = \frac{S_{\phi}}{N} + \frac{\lambda^{2}}{4} \sin 2\phi + \frac{\lambda^{4}}{192} \left[2(-1 + \sigma + 4\sigma^{2}) \sin 2\phi + (1 + \sigma + 4\sigma^{2}) \sin 4\phi \right]$$

$$\begin{pmatrix} (5 - 6 \sigma - 91\sigma^{2} + 364\sigma^{3} - 136\sigma^{4}) \sin 2 \phi \\ + \frac{\lambda^{6}}{23040} \end{pmatrix} + 4(-1 + \sigma^{2} - 28\sigma^{3} + 88\sigma^{4}) \sin 4 \phi \\ + (1 + 2\sigma + 33\sigma^{2} - 196\sigma^{3} + 280\sigma^{4}) \sin 6 \phi$$

$$2 (-7 + 9\sigma + 819\sigma^{2} - 12413\sigma^{3} + 36984\sigma^{4}$$

$$- 33648\sigma^{5} + 10240\sigma^{6}) \sin 2 \phi$$

$$+2 (7 - 3\sigma - 279\sigma^{2} + 7243\sigma^{3} - 38568\sigma^{4}$$

$$+ 58512\sigma^{5} - 20864\sigma^{6}) \sin 4 \phi$$

$$+6 (-1 - \sigma - 91\sigma^{2} + 1381\sigma^{3} - 2872\sigma^{4}$$

$$-3344\sigma^{5} + 7168\sigma^{6}) \sin 6 \phi$$

$$+ (1 + 3\sigma + 279\sigma^{2} - 7235\sigma^{3} + 44136\sigma^{4} - 90384\sigma^{5}$$

$$+ 58240\sigma^{6}) \sin 8 \phi$$
(30)

Setting
$$\sigma = \frac{N}{R} = 1 + \delta \cos^2 \phi \tag{31}$$

where
$$\delta = \frac{\epsilon^2}{1 - \epsilon^2} = \epsilon'^2$$
 (32)

and
$$\eta^2 = \delta \cos^2 \phi$$
 (33)

$$t = \tan \phi \tag{34}$$

We may rewrite (30) as

$$\frac{X}{N} = \lambda \cos \phi + \frac{\lambda^3 \cos^3 \phi}{6} (1 - t^2 + \eta^2) + \frac{\lambda^5 \cos^5 \phi}{120} (5 - 18t^2) + t^4 + 14\eta^2 - 58t^2\eta^2 + 13\eta^4 - 64t^2\eta^4 + 4\eta^6 - 24t^2\eta^6) +$$

$$\frac{61 - 479t^2 + 179t^4 - t^6 + 331\eta^2}{-3298\eta^2 t^2 + 1771\eta^2 t^4 + 715\eta^4} + \frac{\lambda^7 \cos^7 \phi}{-8655t^2\eta^4 + 6080t^4\eta^4 + 769\eta^6} + \frac{\lambda^7 \cos^7 \phi}{-10964t^2\eta^6 + 9480t^4\eta^6 + 412\eta^8} + \frac{6760t^2\eta^8 + 6912t^4\eta^8 + 88\eta^{10}}{-1632t^2\eta^{10} + 1920t^4\eta^{10}}$$
(35)

$$\frac{Y}{N} = \frac{S\phi}{N} + \frac{\lambda^2}{2} \sin\phi \cos\phi + \frac{\lambda^4}{24} \sin\phi \cos^3\phi (5 - t^2 + 9\eta^2 + 4\eta^4) +$$

$$\frac{\lambda^{6}}{720} \sin \phi \cos^{5} \phi (61 - 58t^{2} + t^{4} + 270\eta^{2})$$

$$- 330t^{2}\eta^{2} + 445\eta^{4} - 680t^{2}\eta^{4} + 324\eta^{6} - 600t^{2}\eta^{6}$$

$$+ 88\eta^{8} - 192t^{2}\eta^{8}) +$$

$$\begin{vmatrix}
1385 - 3111t^{2} + 543t^{4} - t^{6} + 10899\eta^{2} \\
- 32802t^{2}\eta^{2} + 9219t^{4}\eta^{2} + 34419\eta^{4} \\
- 129087t^{2}\eta^{4} + 49644t^{4}\eta^{4} + 56385\eta^{6} \\
- 252084t^{2}\eta^{6} + 121800t^{4}\eta^{6} + 50856\eta^{8} \\
- 263088t^{2}\eta^{8} + 151872t^{4}\eta^{8} + 24048\eta^{10} \\
- 140928t^{2}\eta^{10} + 94080t^{4}\eta^{10} + 4672\eta^{12} \\
- 30528t^{2}\eta^{12} + 23040t^{4}\eta^{12}
\end{vmatrix} (36)$$

Arranging (35) and (36) to facilitate computation and setting $\lambda = \lambda - \lambda_0 = \Delta \lambda$ as the longitude difference from the central meridian and dropping out small terms we have

$$\frac{X}{N} = \Delta\lambda \cos\phi + \frac{\Delta\lambda^3 \cos^3\phi}{6} (1 - t^2 + \eta^2) + \frac{\Delta\lambda^5 \cos^5\phi}{120} (5 - 18t^2 + t^4 + 14\eta^2 - 58t^2\eta^2 + 13\eta^4 + 4\eta^6 - 64\eta^4t^2 - 24\eta^6t^2) + \frac{\Delta\lambda^7 \cos^7}{5040} (61 - 479t^2 + 179t^4 - t^6)$$
(37)

$$\frac{Y}{N} = \frac{S_{\phi}}{N} + \frac{\Delta \lambda^2}{2} \sin \phi \cos \phi + \frac{\Delta \lambda^4}{24} \sin \phi \cos^3 \phi (5 - t^2)$$

$$+ 9\eta^2 + 4\eta^4 + \frac{\Delta \lambda^4}{24} \sin \phi \cos^3 \phi (5 - t^2)$$

$$\frac{\Delta \lambda^{6}}{720} \sin \phi \cos^{5} \phi \begin{cases}
61 - 58t^{2} + t^{4} + 270\eta^{2} - 330t^{2}\eta^{2} \\
+ 445\eta^{4} + 324\eta^{6} - 680\eta^{4}t^{2} + 88\eta^{8} \\
- 600\eta^{6}t^{2} - 192\eta^{8}t^{2}
\end{cases}$$

$$+ \frac{\Delta \lambda^{8}}{40320} \sin \phi \cos^{7} \phi (1385 - 3111t^{2} + 543t^{4} - t^{6}) \quad (38)$$

The first three terms of (37) correspond to the functions IV, V and B_5 given in the Army Tech Man TM 5-241-8. The first four terms correspond to the functions I, II, III, and A_6 of the same manual. However, the functions A_6 and B_5 of the manual are truncated versions of the terms shown above.

3.1.1 Meridian Arc Length from Equator

The meridian arc length S is defined in equation (21). Substituting the value of R from (10) into this equation, we have

$$S_{\phi} = \int_{0}^{\phi} a(1 - \epsilon^{2}) (1 - \epsilon^{2} \sin^{2} t)^{3/2} dt$$
 (39)

This may be written as

1

1

1

1

1

ı

1

$$S_{\phi} = a(1 - \epsilon^2) \Pi(\phi, - \epsilon^2, \epsilon)$$
 (40)

where $\Pi(\phi, -\epsilon^2, \epsilon)$ is Lengendre's Normal Elliptic Integral of the third kind. Now

$$\Pi(\phi, -\epsilon^2, \epsilon) = \frac{1}{1 - \epsilon^2} (E(\phi, \epsilon) - (1 - \epsilon^2 \sin^2 \phi)^{-1/2} \epsilon^2 \sin \phi \cos \phi)$$
(41)

where E (ϕ, ϵ) is the incomplete Elliptic Integral of the second kind.

A series expansion for S_ϕ is given in Jordan's Handbook of geodesy, Vol. III, first half. This expansion using all terms involving ϵ through the 10th power is

$$s_{\phi} = a \left(1 - \epsilon^{2}\right) \left(C_{a}\phi - \frac{C_{b}}{2} \sin 2\phi + \frac{C_{c}}{4} \sin 4\phi - \frac{C_{d}}{6} \sin 6\phi + \frac{C_{e}}{8} \sin 8\phi - \frac{C_{f}}{10} \sin 10\phi\right)$$
(42)

where

$$C_{a} = 1 + \frac{3}{2^{2}} \epsilon^{2} + \frac{3^{2} \cdot 5}{2^{6}} \epsilon^{4} + \frac{5^{2} \cdot 7}{2^{8}} \epsilon^{6} + \frac{5^{2} \cdot 7 \cdot 9}{2^{14}} \epsilon^{8} + \frac{7^{2} \cdot 9^{2} \cdot 11}{2^{16}} \epsilon^{10}$$

$$C_{\rm b} = \frac{3}{2^2} \, \epsilon^2 + \frac{3 \cdot 5}{2^4} \, \epsilon^4 + \frac{(3 \cdot 5 \cdot 7) \, 5}{2^9} \, \epsilon^6 + \frac{(5 \cdot 7 \cdot 9) \, 7}{2^{11}} \, \epsilon^8 + \frac{(3 \cdot 5 \cdot 7 \cdot 9 \cdot 11) \, 7}{2^{16}} \, \epsilon^{10}$$

$$C_{c} = \frac{3 \cdot 5}{2^{6}} \epsilon^{4} + \frac{3 \cdot 5 \cdot 7}{2^{8}} \epsilon^{6} + \frac{(5 \cdot 7 \cdot 9)7}{2^{12}} \epsilon^{8} + \frac{(3 \cdot 5 \cdot 7 \cdot 9 \cdot 11)}{2^{14}} \epsilon^{10}$$

$$C_d = \frac{5 \cdot 7}{2^9} \epsilon^6 + \frac{5 \cdot 7 \cdot 9}{2^{11}} \epsilon^8 + \frac{(5 \cdot 7 \cdot 9 \cdot 11)9}{2^{17}} \epsilon^{10}$$

$$C_e = \frac{5 \cdot 7 \cdot 9}{2^{14}} \epsilon^8 + \frac{5 \cdot 7 \cdot 9 \cdot 11}{2^{16}} \epsilon^{10}$$

$$C_{f} = \frac{7 \cdot 9 \cdot 11}{2^{17}} \epsilon^{10} \tag{43}$$

3.1.2 Central Scale Factor

Since the local scale factor increases as a function of the distance from the central meridian, the UTM system has adopted a central scale factor of 0.9996 to equalize the scale errors across the zone width. This scale factor is the one used for this program. Two other scale factors are in use in other areas of the world, such as .9999 used in Canada and 1.0000 used in many European countries. The scale factor is most easily accommodated into the calculation by modifying the semi-major axis by the scale factor as

$$a' = k_0 a \tag{44}$$

where a' is the value to be used in calculating the UTM coordinates and $k_{\rm O}$ is the central scale factor. The units of a used in these equations is in meters instead of the usual units of minutes on the Equator.

3.2 LAT-LONG COORDINATES FROM UTM GRID

Rewriting (19) as

$$\lambda + i \tau = F (x + iy) \tag{45}$$

Now when x = 0, $\lambda = 0$ and then F(iy) = i from (22) and (23)

$$\tau = \int_0^{\phi} \frac{R d\phi}{N \cos \phi}$$
 (46)

$$\frac{d\tau}{dS_{\phi}} = \frac{1}{N\cos\phi} \tag{47}$$

$$\frac{d\phi}{dS_{\phi}} = \frac{1}{R} \tag{48}$$

Expanding F(X + iy) about the point iy

$$\lambda + i \tau = F(iy) + X F' (iy) + \frac{x^2}{2!} F'' (iy) + \frac{x^n}{n!} F^{n'} (iy)$$
 (49)

From
$$F(iy) = i\tau$$
, we have $F'(iy) = \tau'$, $F''(iy) = -i\tau''$, $F^{ii}(iy) = -\tau^{iii}$, $F^{iv}(iy) = i\tau^{iv}$, \cdots $F^{n'} = i(-i)^n \tau^{n'}$

We have

$$\lambda + i^{\tau} = i^{\tau}_{1} + x^{\tau}_{1}' - \frac{x^{2}}{2!} i^{\tau}_{1}'' - \frac{x^{3}}{3!} \tau^{iii} + \cdots \frac{x^{n}}{n!} i^{(-i)}^{n_{\tau}n'} + \cdots$$
(50)

Equating real and imag terms

$$\lambda = x \tau_{1}' - \frac{x^{3}}{3!} \tau_{1}^{iii} + \frac{x^{5}}{5!} \tau_{1}^{v} - \frac{x^{7}}{7!} \tau_{1}^{vii} + \cdots$$
 (51)

$$\tau = \tau_1 - \frac{x^2}{2!} \tau_1^{iii} + \frac{x^4}{4!} \tau_1^{iv} - \frac{x^6}{6!} \tau_1^{vi} + \frac{x^8}{8!} \tau_1^{viii} - \cdots$$

where the subscript one refers to the "footpoint" latitude of a given point of the projection as shown in Figure 4.

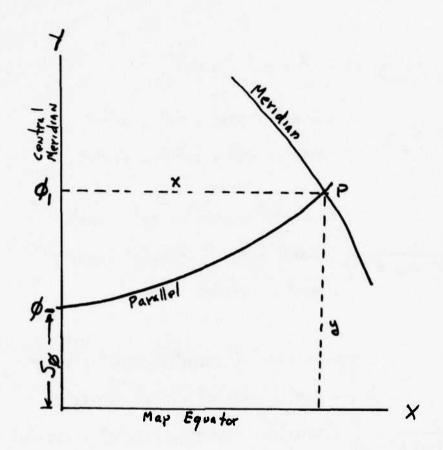


Figure 4. Footpoint Latitude ϕ_{i} , of Point P

from (47), (48) and (28)

$$\tau' = \frac{d\tau}{dS\phi} = \frac{1}{N\cos\phi} \tag{52}$$

$$\tau^{\prime\prime} = \frac{(N\cos\phi)^{1}}{N^{2}\cos^{2}\phi} \frac{d\phi}{dS} = \frac{\tan\phi}{N^{2}\cos\phi} = \frac{t}{N^{2}\cos\phi}$$
 (53)

Similarily with $t = \tan \phi$, $N/R = 1 + \eta^2$ we have

$$\tau''' = \frac{1}{N^3 \cos \phi} \quad (1 + 2t^2 + \eta^2) \tag{54}$$

$$\tau^{iv} = \frac{t}{N^4 \cos \phi} (5 + \eta^2 + 6t^2 - 4\eta^4)$$
 (55)

$$\tau^{V} = \frac{1}{N^{5} \cos \phi} \begin{cases} 5 + 6\eta^{2} + 28t^{2} - 3\eta^{4} + 8t^{2}\eta^{2} \\ + 24t^{4} - 4\eta^{6} + 4t^{2}\eta^{4} + 24t^{2}\eta^{6} \end{cases}$$
 (56)

$$\tau^{\text{vi}} = \frac{t}{N^6 \cos \phi} + 120t^4 + 100\eta^6 - 36t^2\eta^4 - 96t^2\eta^6$$

$$+ 88\eta^8 - 192t^2\eta^8$$
(57)

$$\tau^{\text{Vii}} = \frac{1}{N^7 \cos \phi} \begin{cases} 61 + 662t^2 + 1320t^4 + 720t^6 + 107\eta^2 \\ + 43\eta^4 + 440t^2\eta^2 + 97\eta^6 - 234t^2\eta^4 \\ + 336t^4\eta^2 + 188\eta^8 - 772t^2\eta^6 - 192t^4\eta^4 \\ + 88\eta^{10} - 2392t^2\eta^8 + 408t^4\eta^6 + 1536t^4\eta^8 \\ - 1632t^2\eta^{10} + 1920t^4\eta^{10} \end{cases}$$
(58)

$$\tau^{\text{Viii}} = \frac{t}{N^8 \cos \phi}$$

$$= \frac{t}{N^8 \cos \phi}$$

Placing these values into (51) we have

$$\Delta \lambda = \frac{1}{\cos \phi_1}$$

$$-\frac{1}{6} \left(\frac{x}{N_1}\right)^3 \left(1 + 2t_1^2 + \eta_1^2\right)$$

$$+\frac{1}{120} \left(\frac{x}{N_1}\right)^5 \begin{cases} 5 + 6\eta_1^2 + 28t_1^2 - 3\eta_1^4 + 8t_1^2\eta_1^2 \\ + 24t_1^4 - 4\eta_1^6 + 4t_1^2\eta_1^4 + 24t_1^2\eta_1^6 \end{cases}$$

$$-\frac{1}{\cos \phi_1}$$

$$-\frac{1}{5040} \left(\frac{x}{N_1}\right)^7 \begin{cases} 61 + 662t_1^2 + 1320t_1^4 + 720t_1^6 \\ + 107\eta_1^2 + 43\eta_1^4 + 440t_1^2\eta_1^2 \\ + 97\eta_1^6 - 234t_1^2\eta_1^4 + 336t_1^4\eta_1^2 \\ + 188\eta_1^8 - 772t_1^2\eta_1^6 - 192t_1^4\eta_1^4 \\ + 1536t_1^4\eta_1^8 - 1632t_1^2\eta_1^{10} \\ + 1920t_1^4\eta_1^{10} \end{cases}$$

$$(60)$$

In the coefficient of $\left(\frac{x}{N_1}\right)^7$, all terms containing η , may be deleted without seriously effecting accuracy.

$$-\frac{1}{2} \left(\frac{x}{N_{1}}\right)^{2} + \frac{1}{24} \left(\frac{x}{N_{1}}\right)^{4} (5 + \eta_{1}^{2} + 6t_{1}^{2} - 4\eta_{1}^{4})$$

$$+ 6t_{1}^{2} - 4\eta_{1}^{4})$$

$$-\frac{1}{720} \left(\frac{x}{N_{1}}\right)^{6} \begin{bmatrix} 61 + 46\eta_{1}^{2} + 180t_{1}^{2} - 3\eta_{1}^{4} + 48t_{1}^{2}\eta_{1}^{2} + 120t_{1}^{4} + 100\eta_{1}^{6} + 36t_{1}^{2}\eta_{1}^{4} - 96t_{1}^{2}\eta_{1}^{6} + 88\eta_{1}^{8} + 192t_{1}^{2}\eta_{1}^{8} \end{bmatrix}$$

$$\Delta \tau = \tau - \tau_{1}$$

$$= \frac{t_{1}}{\cos \phi_{1}}$$

$$+ \frac{1}{40320} \left(\frac{x}{N_{1}}\right)^{8}$$

$$+ \frac{1}{40320} \left(\frac{x}{N_{1}}\right)^{8}$$

$$- 2927 \eta_{1}^{6} + 5052 t_{1}^{2} \eta_{1}^{6} - 1536 t_{1}^{4} \eta_{1}^{4}$$

$$- 8808 \eta_{1}^{8} + 27456 t_{1}^{2} \eta_{1}^{8} + 744 t_{1}^{4} \eta_{1}^{6}$$

$$- 11472 \eta_{1}^{10} + 53952 t_{1}^{2} \eta_{1}^{10}$$

$$- 7872 t_{1}^{4} \eta_{1}^{8} - 4672 \eta_{1}^{12} + 30528 t_{1}^{2} \eta_{1}^{12}$$

Since $\Delta \tau$ is the difference of the true isometric latitudes in order to obtain the geodetic latitude difference from (61) we expand $\Delta \phi$ into a series in $\Delta \tau$ as

 $-24960t_1^4\eta_1^{10} -23040t_1^4\eta_1^{12}$

(61)

$$\Delta \phi = \phi - \phi_1 = \Delta \tau \frac{d\phi_1}{d\tau_1} + \frac{\Delta \tau^2}{2!} \frac{d^2 \phi_1}{d\tau_1^2} + \cdots \frac{\Delta \tau^n d^n \phi_1}{n! d\tau_1^n} + \cdots$$
(62)

Now from (46)

$$\frac{d\phi_1}{d\tau_1} = \frac{N_1}{R_1} \cos \phi_1 = (1 + \eta_1^2) \cos \phi_1$$

and by successive differentiation

$$\frac{d^{2}\phi_{1}}{d\tau_{1}^{2}} = -(1 + \eta_{1}^{2}) (1 + 3\eta_{1}^{2}) t_{1} \cos^{2}\phi_{1}$$

$$\frac{d^{3}\phi_{1}}{d\tau_{1}^{3}} = (1 + \eta_{1}^{2}) \left[4t_{1}^{2} + 2(1 + \eta_{1}^{2})(1 - 9t_{1}^{2}) + 3(1 + \eta_{1}^{2})^{2} (5t_{1}^{2} - 1) \right] \cos^{3}\phi_{1}$$

$$\frac{d^{4}\phi_{1}}{d\tau_{1}^{4}} = -t_{1} \left(1 + \eta_{1}^{2}\right) \left[-8t_{1}^{2} + 4(1 + \eta_{1}^{2})(21t^{2} - 4) + 4(1 + \eta_{1}^{2})^{2} (17 - 45t_{1}^{2}) + 3(1 + \eta_{1}^{2})^{3} \right]$$

$$\left(35 t_{1}^{2} - 19\right) \cos^{4}\phi_{1} \qquad (63)$$

Substituting the value of $\Delta \tau$ from (61) and the values of $\frac{d^n \phi_1}{d \tau_1^n}$ from (63) into (62) and deleting terms in η_1 in the coefficient of $\left(\frac{x}{N_1}\right)^8$ as well as taking note that $1 + \eta_1^2 = \frac{N_1}{R_1}$ we have

$$\phi = \phi_{1} - \frac{t_{1}}{2R_{1}N_{1}} \times^{2} + \frac{t_{1}}{24R_{1}N_{1}^{3}} \times^{4} (5 + 3t_{1}^{2} + \eta_{1}^{2}$$

$$- 4\eta_{1}^{2} - 9\eta_{1}^{2}t_{1}^{2})$$

$$- \frac{t_{1}}{720R_{1}N_{1}^{5}} \times^{6} \begin{bmatrix} 61 + 90t_{1}^{2} + 46\eta_{1}^{2} + 45t_{1}^{4} - 252t_{1}^{2}\eta_{1}^{2} \\ - 3\eta_{1}^{4} + 100\eta_{1}^{6} - 66t_{1}^{2}\eta_{1}^{4} - 90t_{1}^{4}\eta_{1}^{2} \\ + 88\eta_{1}^{8} + 225t_{1}^{4}\eta_{1}^{4} + 84t_{1}^{2}\eta_{1}^{6} - 192t_{1}^{2}\eta_{1}^{8} \end{bmatrix}$$

$$+\frac{t_1}{40320R_1N_1^7} \times^8 \left(1385 + 3633t_1^2 + 4095 t_1^4 + 1575t_1^6\right)$$
 (64)

Equation (60) with the terms containing η_1 in the coefficient of $\left(\frac{x}{N_1}\right)^7$ deleted, along with equation (64) are used to determine the ϕ , λ from the given X, Y location. The $\Delta\lambda$ is added to the value of the central meridian to determine λ . The X and Y values used in the equations have the false Easting and false Northing removed.

3.3 COMPUTER CALCULATION OF UTM FROM LAT-LONG

This routine required double precision floating point arithmetic on a Sigma V computer to maintain sufficient accuracy. An outline of the program is as follows.

a. Input

Semi major axis in meters = a

Central scale factor = k_0 (.9996 for UTM)

Inverse flattening factor = 1/f

UTM zone number

Latitude = ϕ radians

Longitude = λ radians

b. Step 1

Calculate

$$a' = k_0 a$$

$$f = (1/(1/f))$$

$$\epsilon^2 = f (2 - f)$$

$$\lambda_0 = (-183 + 6 \text{ (zone No)})/57.29....$$

$$\Delta \lambda = \lambda - \lambda_0$$

$$N = a'/(1 - \epsilon^2 \sin^2 \phi)^{1/2}$$

c. Step 2

Calculate S_{ϕ} from equation (43)

d. Step 3

Calculate x from equation (37)

y from equation (38)

e. Step 4

Add 500,000 meters false Easting to X. Test Y and if negative, subtract Y from 10,000,000 meters false Northing (i.e. add magnitude of Y to 10^6 meters).

3.4 COMPUTER CALCULATION OF LAT-LONG FROM UTM

This routine required double precision floating point arithmetic on a Sigma V computer to maintain sufficient accuracy. An outline of the program is as follows.

a. Input

Semi major axis in meters = a

Central scale factor = k_0 (UTM, K_0 = .9996)

Inverse flattening factor = 1/f

UTM zone number

X = Easting containing false Easting (meters)

Y = Northing containing false Northing (meters)

b. Step 1

Remove false Easting from X

Test and remove false Northing from Y

$$\lambda_0 = (-183 + 6 \text{ (zone no)})/57.29....$$

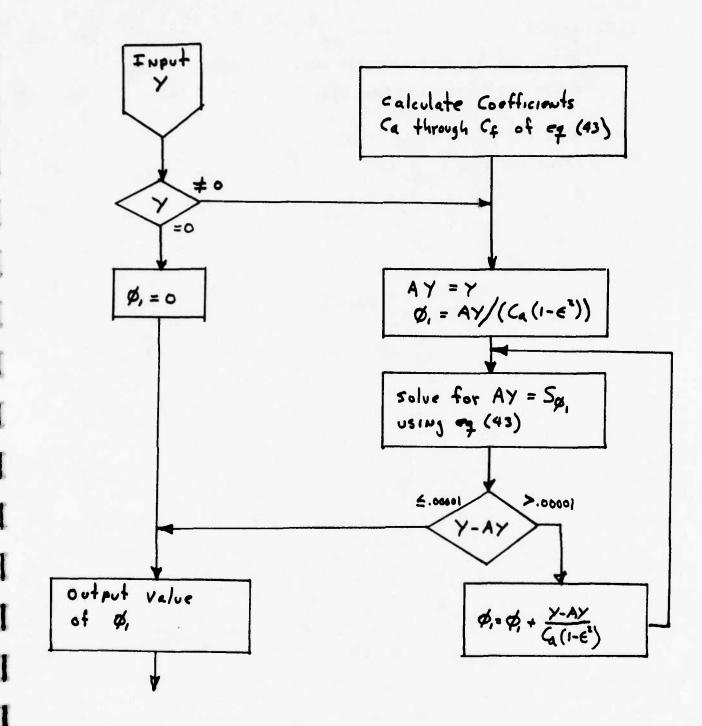
$$a' = k_0 a$$

$$\epsilon^2 = f(2 - f)$$

c. Step 2

Iteriatively solve for footpoint

Latitude ϕ_1 by the following method



- d. Step 3 Solve for $\Delta \lambda$ from equation (60) Solve for ϕ from equation (64)
- e. Step 4
 Solve for λ as $\lambda_0 + \Delta$

4.0 LOCAL COORDINATE CONVERSION

4.1 LAT-LONG TO LOCAL COORDINATES

The local coordinate system chosen for data reduction is a cartesian X, Y, Z coordinate system with the Y axis oriented north at the origin, X oriented to the east at the origin and Z vertical. The X-Y plane is normal to the spheroid at the reference or origin point.

Setting up a geocentric coordinate system with the $X_1 - X_2$ plane in the equatorial plane and X_3 oriented north as shown in Figure 5, the coordinate system X_k' as shown in Figure 6 is related to X_k as follows:

$$x_{1} = x_{1}' \cos \lambda - x_{2}' \sin \lambda$$

$$x_{2} = x_{1}' \sin \lambda - x_{2}' \cos \lambda$$

$$x_{3} = x_{3}'$$
(65)

and

$$x_{1}' = E \cos \phi_{g} + h \cos \phi$$

$$x_{2}' = 0$$

$$x_{3}' = E \sin \phi_{g} + h \sin \phi$$
(66)

where λ is the longitude angle, ϕ is the geodetic latitude, $\phi_{\rm g}$ is the geocentric latitude and h is the geodetic elevation of point M.

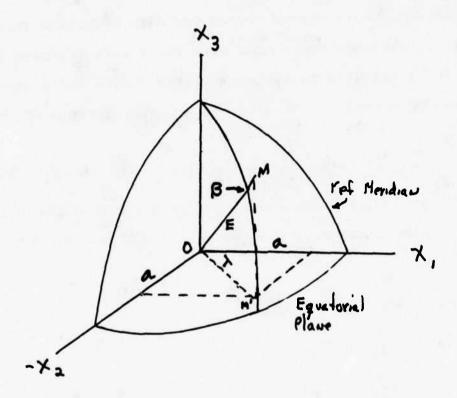


Figure 5. Geocentric Coordinate System

Equation (65) also may be written as

$$x_{1} = \cos \lambda (E \cos \phi_{g} + h \cos \phi)$$

$$x_{2} = \sin \lambda (E \cos \phi_{g} + h \cos \phi)$$

$$x_{3} = E \sin \phi_{g} + h \sin \phi$$
(67)

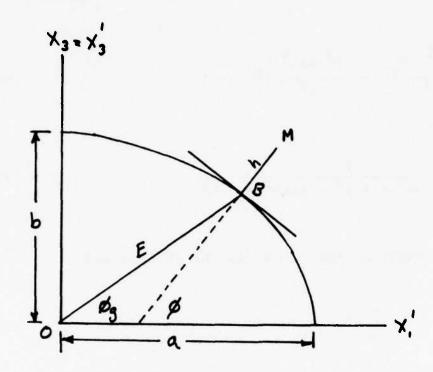


Figure 6. Rotated xk Coordinate System

Now on the surface of the spheroid, the intersection of the x_1 ' x_3 ' plane with the spheroid is an ellipse expressed by

$$\frac{x_1'^2}{a^2} + \frac{x'_3^2}{b^2} = 1$$

$$x_1' = E \cos \phi_g$$

$$x_3' = E \sin \phi_g$$
(68)

So that

$$E^{2} = \frac{\cos^{2} \phi_{g}}{a^{2}} + \frac{E^{2} \sin^{2} \phi_{g}}{b^{2}} = 1$$
 (69)

or

$$E^{2} = \frac{1}{(\cos^{2}\phi_{g})/a^{2} + (\sin^{2}\phi_{g})/b^{2}}$$
 (70)

Since ϕ is the angle of the normal to the ellipse and

$$\tan \phi = -\frac{dx'_1}{dx'_3} \tag{71}$$

differentiating (68) with respect to x_3

$$\frac{x_1'}{a^2} \frac{dx'_1}{dx'_3} + \frac{x'_3}{b^2} = 0 ag{72}$$

So that

$$\tan \phi = \frac{a^2}{b^2} \frac{x'_3}{x'_1} = \frac{a^2}{b^2} \tan \phi_g$$
 (73)

Since $\epsilon^2 = (a^2 - b^2)/a^2$

$$\tan \phi_{g} = (1 - \epsilon^{2}) \tan \phi \tag{74}$$

and

$$E^2 = \frac{b^2}{1 - \epsilon^2 \cos^2 \phi_g} \tag{75}$$

4.1 LOCAL COORDINATE SYSTEM

Let $x_1^{"}$, $x_2^{"}$ and $x_3^{"}$ be a coordinate system with its origin at reference position A as shown in Figure 7.

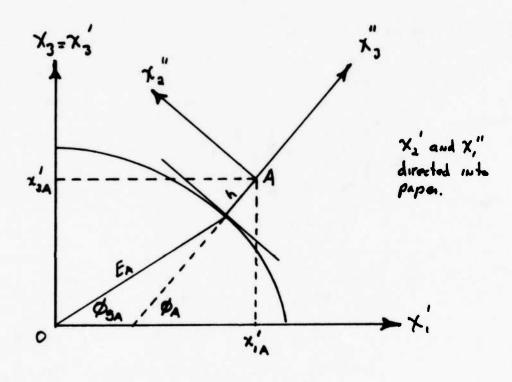


Figure 7. Local Coordinate System with Origin at A

Then

$$\begin{bmatrix} x_1'' \\ x_2'' \\ x_3'' \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ -\sin\phi_A & 0 & \cos\phi_A \\ \cos\phi_A & 0 & \sin\phi_A \end{bmatrix} \begin{bmatrix} x_1' - x_1'_A \\ \dot{x}_2' \\ x_3' - x_3'_A \end{bmatrix}$$
(80)

and

$$\begin{bmatrix} x_{1}' - x_{1}' \\ x_{2}' \\ x_{3}' - x_{3}' \\ A \end{bmatrix} = \begin{bmatrix} \cos \lambda_{A} & \sin \lambda_{A} & 0 \\ -\sin \lambda_{A} & \cos \lambda_{A} & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_{1} - x_{1A} \\ x_{2} - x_{2A} \\ x_{3} - x_{3A} \end{bmatrix}$$
(81)

Substituting back into (80)

$$x'' = AD (82)$$

where

$$D = \begin{bmatrix} x_1 - x_{1A} \\ x_2 - x_{2A} \\ x_3 - x_{3A} \end{bmatrix}$$
 (83)

and

$$A = \begin{bmatrix} -\sin \lambda_{A} & \cos \lambda_{A} & 0 \\ -\cos \lambda_{A} & \sin \phi_{A} & -\sin \phi_{A} & \sin \lambda_{A} & \cos \phi_{A} \\ \cos \phi_{A} & \cos \lambda_{A} & \cos \phi_{A} & \sin \lambda_{A} & \sin \phi_{A} \end{bmatrix}$$
(84)

The local coordinates can then be determined by use of equation set (67) to solve for X and X_A utilizing (74) and (75) to determine ϕ_g , ϕ_{gA} , E and E_A .

4.2 LOCAL COORDINATES TO LAT-LONG

The inverse solution is not as straight forward as the LAT-LONG to LC in that the set of equations (67), (74), and (75) relating X to LAT-LONG-h are not linear. To solve this set, some sort of iterative approach is necessary. One method would be to rearrange (82) as

$$x = A^{-1} x'' + x_A \tag{85}$$

and then iteratively solve for LAT-LONG from x. This, however, introduces some error in the calculation in that errors in the inversion of A are propagated to the answer. A better approach is to estimate the geographic coordinates and solve for the LOCAL coordinates in a manner to minimize the square error between the input local coordinates and the computed local coordinates derived from an estimate of the geographic coordinates. Figure 8 gives a block diagram of the solution where

Geographic coordinates are

$$W_1 = \phi, W_2 = \lambda, W_3 = h$$
 (86)

Local X Y Z are

$$x_1'' = x, x_2'' = y, x_3'' = z$$
 (87)

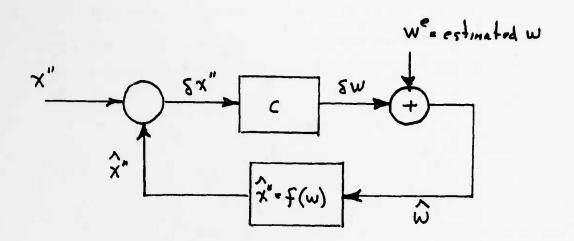


Figure 8. Inverse Solution Block Diagram

In this solution, the block relating x'' as a function of W is the LAT-LONG to local coordinate conversion routine outlined in 4.1. Matrix C relates the geographic error vector to the local coordinate error vector in a manner to minimize the square of the error between x'' and \hat{x}'' . The vector equations are

$$B^{T}B \delta_{W} = B^{T} \delta_{X}^{"}$$
 (88)

or

$$\delta_{\mathbf{W}} = (\mathbf{B}^{\mathbf{T}}\mathbf{B})^{-1} \mathbf{B}^{\mathbf{T}} \delta_{\mathbf{x}}^{"} = \mathbf{C} \delta_{\mathbf{x}}^{"}$$

where

$$B^{T} = -\begin{bmatrix} \frac{\partial x_{1}}{\partial w_{1}} & \frac{\partial x_{2}}{\partial w_{1}} & \frac{\partial x_{3}}{\partial w_{1}} \\ \frac{\partial x_{1}}{\partial w_{2}} & \frac{\partial x_{2}}{\partial w_{2}} & \frac{\partial x_{3}}{\partial w_{2}} \\ \frac{\partial x_{1}}{\partial w_{3}} & \frac{\partial x_{2}}{\partial w_{3}} & \frac{\partial x_{3}}{\partial w_{3}} \end{bmatrix}$$
(89)

From (82) and (83)

$$x'' = Ax - Ax_A \tag{90}$$

So that

$$B = -AF (91)$$

where A is defined in (84) and

$$\mathbf{F} = \begin{bmatrix} \frac{\partial \mathbf{x}_1}{\partial \mathbf{W}_1} & \frac{\partial \mathbf{x}_1}{\partial \mathbf{W}_2} & \frac{\partial \mathbf{x}_1}{\partial \mathbf{W}_3} \\ \frac{\partial \mathbf{x}_2}{\partial \mathbf{W}_1} & \frac{\partial \mathbf{x}_2}{\partial \mathbf{W}_2} & \frac{\partial \mathbf{x}_2}{\partial \mathbf{W}_3} \\ \frac{\partial \mathbf{x}_3}{\partial \mathbf{W}_1} & \frac{\partial \mathbf{x}_3}{\partial \mathbf{W}_2} & \frac{\partial \mathbf{x}_3}{\partial \mathbf{W}_3} \end{bmatrix}$$
(92)

Since

$$\phi_{\mathbf{g}} \approx \phi \tag{93}$$

we may approximate (67) as

$$x_{1} \approx (E + h) \cos \phi \cos \lambda = (E + W_{3}) \cos (W_{1}) \cos (W_{2})$$

$$x_{2} \approx (E + h) \cos \phi \sin \lambda = (E + W_{3}) \cos (W_{1}) \sin (W_{2})$$

$$(94)$$

$$x_{3} \approx (E + h) \sin \phi = (E + W_{3}) \sin (W_{1})$$

Then

$$\frac{\partial x_1}{\partial W_1} = -(E + W_3) \cos(W_2) \sin(W_1)$$

$$\frac{\partial x_2}{\partial W_1} = -(E + W_3) \sin(W_2) \sin(W_1)$$

$$\frac{\partial x_3}{\partial W_1} = (E + W_3) \cos(W_1)$$

$$\frac{\partial x_1}{\partial W_2} = -(E + W_3) \cos(W_1) \sin(W_2)$$

$$\frac{\partial x_2}{\partial W_2} = (E + W_3) \cos(W_1) \cos(W_2)$$

$$\frac{\partial x_2}{\partial W_2} = (E + W_3) \cos(W_1) \cos(W_2)$$

$$\frac{\partial x_1}{\partial W_3} = \cos (W_2) \cos (W_1)$$

$$\frac{\partial x_2}{\partial W_3} = \sin (W_2) \cos (W_1)$$

$$\frac{\partial x_3}{\partial W_3} = \sin (W_1)$$
(95)

4.3 COMPUTER CALCULATION OF LOCAL COORDINATES FROM GEOGRAPHIC COORDINATES

The computer program utilizes equation sets (67), (74), (75), (82), (83) and (84) to determine the local cartesian coordinates. Although some problems can occur in solving for points close to the coordinate origin where the major positional difference is altitude, utilization of double precision arithmetic on the Sigma V computer appeared to be quite adequate for this method of solution. This avoided the problem of requiring different routines for different regions.

The method of solution is as follows:

Step 1

Input

a = Semi major axis in meters

1/f = Inverse flattening factor

R; = Reference Lat-Long in radians, altitude in meters

W_i = Geographic coordinates of point to be converted in LAT, LONG in radians, altitude in meters

Step 2

Calculate

$$f = 1/(1/f)$$

$$\epsilon^2$$
 = f(2 - f)

$$b = a(1 - f)$$

$$E_A = b/(1 - \epsilon^2 \cos^2 \phi_A)$$

$$\phi_{g_A} = \tan^{-1} ((1 - \epsilon^2) \tan \phi_A)$$

Set up A array equation (84).

Calculate

$$x_A$$
 as RX_i from equation (67)

Step 3

Calculate

$$E = b/(1 - \epsilon^2 \cos^2 \phi)$$

$$\phi_g = \tan^{-1}((1 - \epsilon^2) \tan \phi)$$

x as PX_{i} from equation (67)

Step 4

$$x'' = A(x - x_A)$$

4.4 COMPUTER CALCULATION OF GEOGRAPHIC COORDINATES FROM LOCAL COORDINATES

The program follows the method outlined in 4.1 utilizing the conversion method of 4.3 to convert estimated geographic coordinates to local coordinates. Double precision on the Sigma V is utilized in the arithmetic and appeared to be more than adequate in the solution. A test of all programs was run utilizing the UTM-GEOGRAPHIC routines as well as the LC-GEOGRAPHIC. This test involved setting a reference on a reference meridian and offsetting the point in UTM grid by increments of 10 meters in Northing and Easting and varying altitude from 0 to 500 meters in steps of 100 meters. The UTM points were converted to Geographic to LOCAL to GEOGRAPHIC to UTM with an error of less than .0001 meters altitude, .001 meters in X and Y and 1.0 x 10⁻⁸ radians.

The inverse solution method is as follows.

Step 1

Input

a = semi major axis in meters

1/f = inverse flattening factor

 R_i = reference geographic coordinates in ϕ , λ , h

x" = local cartesian coordinate value of the point.

Step 2

Calculate

$$f = 1/(1/f)$$

$$\epsilon^{2} = f(2 - f)$$

$$b = a(1 - f)$$

$$E_{A} = b/(1 - \epsilon^{2} \cos^{2} \phi_{A})$$

$$\Phi_{g_{A}} = \tan^{-1} ((1 - \epsilon^{2}) \tan \phi_{A})$$

Set up A array equation (84).

Calculate

XA as RX; from equation (67).

Step 3

Choose initial $W^e = R$.

Step 4

Iteration procedure as in Figure 8 Calculate

$$E = b/(1 - \epsilon^2 \cos^2 \phi)$$

$$\phi_g = \tan^{-1} ((1 - \epsilon^2) \tan \phi)$$

x as PX from equation (67)

Step 5

$$\dot{\mathbf{x}}^{"} = \mathbf{A} (\mathbf{x} - \mathbf{x}_{\mathbf{A}})$$

$$\Delta \mathbf{x}^{"} = \mathbf{x}^{"} - \dot{\mathbf{x}}^{"}$$

Test Δx

If $\Delta x < .01$ stop iteration.

Step 6

Set up F array as in (92).

Calculate B and B^T as in (91).

Calculate $(B^TB)^{-1}$ B^T = A

Calculate new W^e as W^e-A $\Delta x''$ Return to Step 4.

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- 3. Colvocoresses, Alden P., "A Unified Plane Coordinate Reference System", World Cartography, Volume IX, United Nations Publications.
- 4. Jorden-Eggert, "Handbook of Geodesy", Volume III, First Half, Washington, Army Map Service Translation, 1962.
- 5. Levine, Daniel, "Radargrammetry", McGraw Hill, 1960.

MAIN LINE TEST PROGRAM DIMENSION 1_Z(c0), LCE(20), LCN(20), K(3), W(3), XX(3), ELEV(20), ALC(20, DIMENSION ISNLI(20), IDLI(20), IMLI(20), ISNLN(20), IDLN(20), IMLN(20) READ 1005/15WLI(1), IDLT(1), IMLT(1), SECLT(1), ISNLN(1), IDLN(1), DIMENSIEN SECLI(20), SECLY(20), RLAT(20), RLBW(20) HLAT(1)=HAFA(1SNLT(1)+IULT(1)+IMLT(1)+SECLT(1)) KLON(I) * KAF & (| SNEN(I) > I UEN(I) > I MEN(I) > SECEN(I)) DIMENSION A(10) + (10) + 111TLE (10,80) + 5CALE (3) FUNNATIS CENTRAL SCALE FACTOR = \$F8.4) 1945111 39 JELE FAEC 15137 (A-4,8-2) DIMENSION 12(CO) EAST (20) NORTH (20) FURMAT (1A122142F10-C21A122142F10-0) 1003/(1117LE(1/h)/M=1/50) READ 1003/ (ITITLE (I) J) 231/80) DAIA LUN/3/-2357795130823217 1-201 = 1-2014(ALBY(11))+ DAUBLE PRECISION LCEALCY DUUBLE PRECISION NORTH F (1 CONE . E.J. 0) I CUNE . 60 1+ (12076 - cu - 61) 129hE=1 READ 10021A(1)11(1) 1006, SCALE (K) REAU 1002, SCALE (1) *IMEN(I) SECEN(I) FURMAT (SF40.0) 24 4C 11=1.4 FURMAT (BUA1) FBRNA I (5) 2C) DB 10 1=1,10 06 11 1=1,10 DB 40 1=1, V UB 12 1=1,3 KEAU 1004. DO 15 1=1,N FURMAT(1HJ) FERMAT(111) 1001 PRINT 1008 ·9C+621=7 KE1; JEC TYIN. LZTYA レスコエユ LZIYA C . 1004 1003 1002 1004 1001 1006 1000 V 15 15 , J -13: 21: 54: 6 56: 27: 29: 38: * 11: ** 50: 23: 0 9: 70 3 10: 5 18: 55: 25: 28: 31: 32: 33: 34: 35: 36: 37: 39: + C: 41: 45: 4:0

FORMAI (+A.SUTE LEVES124SEASTINGS1146NURININGS9XSEATITUDES9XSEBNGIT PRINT 1018/12(11),EAST(11),NGRT4(11),1ST,10T,1MT,ST,15L,10L,1ML,SL CALL LLFAY(12,11),EAST(11),NBRTH(11),SCALE(K),A(1),F(1),ALA,ALB) *UDES/20x3/LTEnS\$12x4PLTERS\$9x\$U\$3x\$M\$3x\$SEC\$7x\$0\$2x\$M\$3x\$SEC\$/) PRINT 1007, ISNLT(11), ICLT(11), 14LT(11), SECLT(11), ISNLV(11), CALL LLFXY(12mEF, REFE, REFN, SCALE(K), A(1), F(1), F(1), H(2)) IF (1.64.5) 12(11)=126NE;EAST(11)=X;NUMTH(11)=Y FURMAI (7X1 1315X12F18.415X12 (1A1,2131 F.412A)) KEAU 1017,1_2(1), LCE(1), LCN(1), ELEV(1) *10CN(11)*1M_V(11)*SECE*(11)*128VE*X*Y UEGAE (4(1), 11ST, 110T, 11MT, SST) UEGRE (3(2), 113L, 110L, 11ML, SSL) 1003, (1111LE (1, MM), MM=1,80) 1003/ (IIIILE (1, MK), MM=1,80) KEAU ICITAIL(I) JEAST(I) JUBRIH(I) I 101 = 1 A BS (| 10 |) J | 10 L = 1 A BS (| 10 L) DEGRECALA, IST, 101, 1M1, ST) CALL DEGRE (ALU, ISL, IDL, IML, SL) IDI = I ABS(IDT), IDL = I ABS(IDL) READ 1017, 12REF, REFE, HEF'S REPEAT 2005 FOR 1=(15M) KEPEAT +001FBR I=(11) 10J6, SCALE (<) PRINT 1006/SCALE(K) FBKMA1 (13, 3F20.0) IF (L.Ew.D) STOP IF (M.EG.O)SIBP DB 240 11=1,M KEAU 100457 READ 10041 PRINT 1000 PRINT 1013 PRINI 1001 CENTINDE CONTINUE CONTINUE CGNTINCE CONTINUE CUNTINUE X(3) *C. LETEL レスコピュ CALL CALL CALL 1017 1018 101/ 100 VCC 210 240 204 70: 45: :94 40. 525 53: 54: 77: :64 47: 40: 50: 55: 56: 57: 58: 59: :09 61: 67: :69 72: 74: 75: 76: :08 51: 35: 63: 64: :99 68: 78: 83. 84: 86: 65

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FURMAT (4x, S_A] I TUDES, 9X, SLONGITUDES, Z7X, SEASTINGS, 11X, SNORTHINGS
                                                                                                  CALL AYPLL(120NE, X, Y, SCALE (K), A(1), F(1), W(1), W(2))
PRINT 1024, XA(1), AX(2), AX(3), 128NE, X, Y, W(3)
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SUBREUTINE CHAVERTS LATITUDE AND LENGITUDE THE UTM COORDINATES CA=1.+.75*E+45.*E2/64.+175.*E*E2/256.+11025.*E4/16384. Cb*.75*E+E2*10*/16*+E*E2*525*/512*+E4*2E05*/2048* SUCHEUTINE AFFIL (NGZ, A, Y, KO, EA, EFT, FLA, FLB) CC=EE+15./64.+E+E2+105./256.+E4+2205./4096. IMPLICIT JUJBLE PRECISION(A-4,8-2) CD=E*E2*33./512.+E4*315./2043. IF (DL - LI - - 5 - 2) JL = DL + 360 - /RHBJ DAIA MHBD/57.495/79513082321/ LOZ=LONG OF CENTRAL MERIOJAN IF (UL - 61 - 5 - 2) UL = DL - 360 - 7 RHBD FLA=LATITUDE IN RADIANS FLO = LONGITUDE IN RADIANS XXX = PLANE CU-BRDINATES KUSCENINAL SCALE FACTOR DEUGLE FRECISION KINIKO *FLA)+(E/& *SIN(8 * *FLA)) EFISINVERSE FLATIEVING N#A/USGAT (1.-E #SNFL A2) ETAS=E/(1+-E) +CNFLAP EASEMI MAUGE AXIS NOT NUMBER OF LENE SNF LAKESNFLA * UNFLA CNFLAZ=CNFLA*CNFLA CE=E4+315+/16584+ TSEESNF LAZZONFLAZ CNF LA #UCBS(FLA) SNF LAWUS IN (FLA) LUZ=-123+5+\bc ETA4=EIAS+ETAS TSU2=150+153 FL4=L02/K+03 774-874-70 E = F * (Z-F) E4=15412 F=1./2F1 A = F A * KU 7+7=27 JU J J JJ J J 165 20 28: 29: .. 10: 15: 30: 21: 23: 54: 26: 27: 30: 32: 35: 3/: 41: 00 9 25: 36: 39: +0 .. 77 #

YF1#S+N/S• #JE #SNFEA#CNFEA+N*DE4/24• #SNFEA# (CNFEA) ** G* (D• #106+9• * Yrd#n*OL4*0.4/40320**SNFLA*(CNFLA)**/*(1385**3111**TSQ+543**TSQ2 XF3887*10***7*(CBS(FLA))**7/5040**(61**4790*1504179**75041504179** XF1.6.11.6.*ETAS**ETAS**ETAS**ETAS**EFTAS**TSE**ETTAS**ETAS***ETAS YP14=80.*E | A4. E | AS. | SU-192. *E | A4. E | A4. E | SU YP12=61 -- 38 - + | SU+TSC++2+27U - +ETAS-35U - + TSU+ETAS XP12#5**13**TGU+[SQ**2+14**ETAS+58**|SG*ETAS XF180*UL*U27L3+0+(ULXC))**3/6**(1**15G+ETAS) YP13=445 **ETA++324 **ETA+*ETA5 *680 **ETA4*TSG YF11=N*DL+*JLZ//20.*SNFLA*(CNFLA)**5 YPZ#YP11*(YD1C+YP13+YP14) IF (YI-LI-D) Y=100000000-YI XP111N*(O[XIN] **5/100. XFCHXF11+(XP1C+XP1G) XTH (XF1+XF2+XFG) (714224114) # 1 4 OLXCN#UL*CNFLA * E[AS+4.*E[A4) ドメナ・000000111× *TS-32*15-2) YaYI 54: 61: * + + 45: .94 :/4 49: 50: 52: 55; 56: 57: 58: 56 :09 62: 63: :+9 : 09 20 B-52 SUBSECTIVE CONVENTS UTM X,Y COURDINALES INTO LAT. AND LUNG. IN RAD AY*FAC*(AC*FEL1*BC*DSIN(2**FEE1)+CC*DSIN(4**FEE1)*DC*DSIN(6**FEE1) CC=(E4*15./54.+E6*1C5./256.+E8*2205./4096.+E10*10395./16384.)/4. AC=1.+.75*ES+E4*45./64.+E6*175./256.+E8*11025./16384.+E10* BC=(-/b+E3+E4+1b•/16•+E0+52b•/515•+E8+223b•/2048•+E10* DC=(E6*35./51c.+Es*315./2048.+E10*31185./131072.)/6. EC=(E8+310+/16384++E10+3465+/65536+)/8+ +EC+USIN(8+*FEE1)-FC+USIN(10+*FEE1)) DEUBLE PRECISION NIVLAMOIFALAMENALAM IMPLICIT JUJELE FRECISIEN(A-H,8-Z) IF (Y • 6E • 1 3000000 •) Y = 10000000 • - YT RLUNG = LUNGIIOUE IN RADIANS UAIA CEN/57.235/79513082321/ KLAT = LAIIJUDE IN RADIANS USF = CENTRAL SCALE FACTOR FL=(E10+693+/131072+)/10+ FR INVERSE FLATIENING * SEMI MAJOH AXIS 12765-705530-172. IF (Y - NE - 0) 48 14 102 INTEGER GAMD, GAMM NEDNE = OFM ZONE FEE1=AY/(FAC+AC) LCM=-163+6*VZONE ES=2./F-1./(F*F) 43659./65530. FALEAL+ (1 -- ES) LAMCM=LCM/C9N X=X1-500000. £10=£6*£+ 68 10 103 YD-Y= 710X E4=ES+ES AL=CSF * A E6=E4+ES EX=E4+E4 FEE1=0. AYBY 105 104 J J 0 × 00 5 11: 39: + 0 10: 14: :51 .9 17: 0 19: 30: 22: 23. . 40 25: 56: :/2 300 .60 30: 31: 32: 33: 34: 35: 36: *0.

SUBRCUTING LEFXY (NZENE,XI,YI,CSF,A ,F,ALAI,ALBNG)

F118+XX/(B**X14N1)+(XNB*(X/(B**X1)))*(B*+8.40)*F1B+B1AB+K14N1) FP12=(100**ETA6-66**T2E4-90**T4E2+88**ETA8+225**T4E4+84**T2E6* FP11=(61-+90-+72+46-+ETA2+45-+T4-252-+T2E2-3-+ETA4) TLM1=(0++6+E1A2+28+TE+3+ETA4+8+14E2) EIA2=(ES/(1.-LS))+DC8S(FEE1)+DC8S(FEE1) FPI3=1385++3653+T2+4095+*14+1575+F6 FT2=(XND*(X/(720**R1))) + (FP11+FPT2) 1F(DAbs(Y)1F).LI..COUI)ub 19 103 [L1=XN-(XV3/6.*(1.+2.*T2+E1A2)) FIGH (XXX (40320+4X1))) *1111 WEDSGRT (10-ES#FEESIN#FEESIN) FEEDIF=1+(F11-F12+FT3) IF (Y.EG.O.) FELUITEO. Tb 105 IF (Y-EG-0-)38 TB 106 R1=N1+(10=ES)/(8+2) AAY=YUIF/(FAC+AL) FEESINALSIN (FEE1) FEECUS (FEE1) T*FEESIW/FEECUS ETA4=ETA2*ETAC EIA6=EIA4+ETAC EIAS=EIA4*ETA4 FEE1=FEE1+AAY IF (X.E4.0.) 38 TELZ= [Z*E [AZ TZE4=TZ*ETA4 T422=14*E1A2 T4E4= T4+ETA4 12E6=12+£TA5 ZES=TZ*ETA8 アメルアメルでメルカでメ NY X + N N X # + N Y XXXXXXXXXX 22X+SZXHONX * 192 *12E3) オアメキのZXHIZX ZX*ZX*ZXX 66 16 104 T+=T2+12 10=14+12 NIFAE/N **リアノベリアメ** T2=T+1 103 106 ** 46: ¥ 9: 50: 51: 52: 53: 54: 55: :95 57: 500 :65 60: :19 .29 94: : 69 :99 : 19 68: :69 70: 71: 72: 75: 77: 78: 79: 85: 63: 7.3: 14: 16: 80: 81: **

Parent d

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PX(1) #DCGX(x(z)) * (RADF*DCGS(PHIPG) +x(3) *DCGS(x(1)))
PX(Z) #USI *(x(z)) * (RADF*DCGS(PHIPG) +x(3) *DCGS(x(1)))
PX(G) #RADF*DS_Y(FHIPG) +x(3) *DCGS(x(1)))
                                                                                                        KAUP=bazusaRI(1.-EE+CBSLATP+CBSLATP)
                                                                                                                                                                                                                                                                          5
                                                                                                                                                                                                                                                                          IF (DAES(X(1)-AE(1)).61..51)ut TS
                                                                                                                                                                                                                 XE(1) # XE(1) + A(1) U) * (PX(U) - KX(U))
                                                                                                                PHIPGHUATAN ((1.-EE)+DIAN(N(1)))
                                                                                                                           BUIRUI COSLATE, KADP, PHIPS
                                                                                                                                                                                                                                                                                                                                                                                            EH#SL#ST
                                                                                                                                                                                                                                                                                                                                                                                                                =EH+C1 #SL
SET INITIAL CUNDIFIENS
                                                                                                                                                                                                                                                                                                                                                                                                      =-E-+CT
                                                                                                                                                                                                                                             TEST FOR CONVERGENCE
                                                                                               CUSLAIP=UCHS(M(1))
                                                                                                                                                                                                                                                                                                                         UX(1)=x(1)-xE(1)
                                                                  START ITERATION
                                                                                                                                                                                                                                                                                                                                                                         C1=0C88(x(1))
                                                                                                                                                                                                                                                                                                                                                     ((2)v)SA)O=17
                                                                                                                                                                                                                                                                                                                                                                SL=0817(x(2))
                                                                                                                                                                                                                                                                                                                                                                                  ST#DSIN(A(1))
                                                                                                                                                                                                                                                                                                                                             REERAUF+2(1)
                            DB 10 1#1#3-
                                                                                                                                                                                                        UB 20 0=1.3
                                                                                                                                                                                                                                                                 DB 36 1-13
                                                                                                                                                                                                                                                                                                                UC 40 1=1.3
                                                                                                                                                                                     DE 20 1=1,3
                                                                                                                                                                                                                                                                                                                                   BUILDI UX
                                                                                                                                                                 BULL FX
                                      W([)=K(])
                                                                                                                                                                                                                          BULFUL XE
                                                                                                                                                                                              XE([)=C.
                                                                                                                                                                                                                                                                                                       CONTINCE
                                                                                                                                                                                                                                                                                                                                                                                            1(2,1)=
                                                せいしがい か
                                                                                                                                                                                                                                                                                    CONTINUE
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R(1), H(2), H(3) = LAI, LUNG, ELEV OF LUCAL REF IN RADIANS AND METERS GEBILL ENTRY USED FOR KULTIPLE CONVERSIONS OF POINTS USING IME SAME KEFEKENCE. BEFORE USING GEOTLC! AN INITIAL CALL OF LLILC MUST BE MADE TO INITIALIZE SUBABUTINE TO LOCAL REFERENCE M(1) = LAIALSNUAELEY OF POINT IN BE CONVERTED X(1) X(2) X(3) = EASTA NORTHA VERT FROM REFERENCE RA(2)=+A(1,1)*(RADA+DC8S(PH136)+R(3)*DC8S(R(1))) KX(1) # A (1 / N / K A D K * D C B S (PH] 水心) + K (3) * D C B S (K (1))) CONVERIS RESCRAPHIC COUNCINATES TO LUCAL XIY, Z DIMENSION A(3,3), 44(3), PA(3), X(3), K(3), K(3) 17 (1) # 17 D C (1) / (D F [1 0) + 1 (3) + 1 O C ((1))) RADA#db/USURT(1.+EE*CBSLATR+CBSLATR) HAUP=BB/USJ4T(1.-EE+CBSLATP+CBSLATP) IMPLICIT JUJSLE PRECISISM (A-4,9-2) BUTPUT FIEL, BOICUSLATRIRADRIPHIRG PHIRGEDATAN((1.-EE)+DTAN(R(1))) AE & SEMI MAJUR AXIS IN NETERS EF1 = 1/F INVERSE FLATTENING A(3,2)==A(2,3)*A(1,1) A(C1)=-A(1,2)*A(3,3) A(2,2)=A(3,3)+A(1,1) A(3,1) = A(2,3) + A(1,2) CESEATE CUBS(R(1)) CDSLAIP=JCBS(x(1)) ((ハ) ビ) フーハコール (ビ (ハ)) A(<,3)=UC3S(R(1)) A (1,5)=(C45(A(2)) A(3,3)=USIN(R(1)) ENIRY LEGILLI(NAN) UD=AE+(1+++) EE=F + (c. -F) BULFUT KX A(1,3)=0. F = 1 - / E + 1 X U Y J J J U J しょう JJ X J 19: 29: 30: 37: 30 :92 34: 35: ..9 1: 2000 11: 12: 13: 0 9 17: 20: 21: 22: 23: 54: 27: 28: 32: 36: 38: 39: 40: 41: + 25:

SUBARULINE LLILL (RIVINIALAELEFI)

```
UCIPUT AADPAPAJPG

PX(1)#DEGG(K(L))*(AADP*DCGS(PAIPG)+%(G)*DCGS(W(1)))

PX(2)#DSIZ(%(L))*(AADP*DCGS(PAIPG)+%(G)*DCGS(%(1)))

PX(2)#DSIZ(%(L))*(AADP*DCGS(PAIPG)+%(G)*DCGS(%(1)))
                                                                                                             X (1) = X (1) + A (1, U) + (PX(U) - KX(U))
PALPORCATAZ((T.+FE)+DIAZ(>(L))
                                                                           DG 20 1=1,3
x (1)=0.
DG 20 0=1,3
                                                      BUILDI PA
                                                                                                                        RELIGEN
                                                                                                              × v.
4 4 4
4 0 0
. . . .
×
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                                # # X ::
                                                      *64
                                                                555:
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SUBRBUILLE DEURE (MADAISMAIDAIMAFS) DOUGLE PRECISION FSARADADDAUMAFSACON IF (DAUS (6J.-F.) - GT. COUI) RETURN UAIA CON/3/-235/79513062321/ F (IM . NE . OU) RE IURA 10=10+1S14N(1, KAD) リビ=しせいキジネンS(スパリ) 10=151GN (10, RAD) - 5= (Dri-]in) *60. .00 = (U1 − UU) = MU 1M=1M+1 SN#1H KE LUKN Naby. FS=C. 17: 18: Degrees from angle in radious

1: FUNCTION AMENISMISMISSEC)

DEUBLE PRECISION AMENISMISSECTON AND

DAIA LUNISMISSESIM

H: AND MINTON SECTIONS

H: RAPAMANGEN

E: RAPAMANGEN

F((IU-EJ-O) AND (ISN-ED-IH-))RAFAM-RAFARETURN

REICRN

REICRN

HEICRN

HEICRN

HEICRN

HEICRN

RADIANS FROM ANGLE IN DEG, MIM, SEC

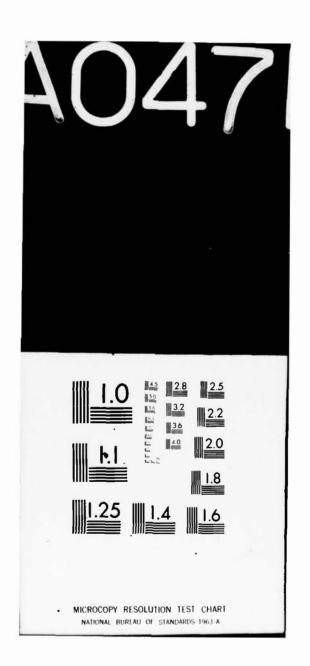
1: FUNCTION AZJIA(ANJ)
2: DEUDLE PRECISION CONJANGJOD
3: DAIA CONJANGJOD
4: DUBANG*CON
5: NZUIM#(DD+186.)/6.
6: IF(NZUIM*EG.O)NZUIM#1
7: RETURN
8: END

UTM ZONE FROM ANGLE OF LONG IN RADIANS

DIMENSION WA MUST BE EDUAL OF GREATER THAN N+2 IMPLICIT DUUSLE PRECISIBN (A-H.9-2) MATHIX INVERSION ROUTINE INVERIS N ST N MATRIX IN A ARRAY ALICHLUM, LIEALICHLUM, LIZA(N+2,1) IF (AMAX-DABS(A(J)X)) 85,100,100 A(-1) = A(-1) - A(1CBLUM) + 1A(N+1, 1CB_CUM) #A(N+1, 1CB_CUM)+1. IF (IRUM - ICULUM) 140,260,140 (L1 - 1C9Lum) 40C,550,460 (アス・ス・4)アスII4FC JZII0のピカコS IF (A(N+1, K)-1.)80,100,740 A(N+2,1)=A(ICOLUM,ICBLUM) IF (A(N+1, J)-1.)60,105,60 ALIRBALL) = ALICELUMAL) DETERM#DETERM*A(N+2,I) A(ICBLUM, ICBLUM) = 1.0 DIMENSION ACKENKI A(ICCLUM, L) # SWAP DEIERM # - DEIERM SHAP # A(INDW.L) 1 = A(L1, ICSLUM) A(INN+E)=ICBLOM UB 550 L1 = 1.N A(L1, ICBLUM) = 0. DE 200 L = 15N 38 350 L = 11N D# 1CU K # 110 NA # 1 05# BO 06 550 1 = 1.N D# 105 U = 15N スのと!!!!!!!! D8 80 0 = 1.N AMAX = A(JI) A (*+1.0)=0. וכפרחש = ע DE LEXME C. THE WANT CONTINCE CONTINUE AMAX=0. 105 140 202 360 380 100 100 350 400 S 85 S.V いししい 56: 30: 'n 31: - am + .. 11: :91 18: 21: 25: 23: 55. 27: 28: 29: 35: 33: 34: 35: 36: 37: 39: +0. × 20 50 10: 15: 13: * 5: 17: 19: 20: 24: 38:

```
44: 550 CENTINCE
45: L = N + 1 - 1
47: L = N + 1 - 1
47: L = N + 1 - 1
48: 630 UNDA=A(L,N+1)+1
50: UCGLUM=A(L,N+2)+1
50: DU 705 K = 14N
51: SWAP = A(4,0Rux)
52: A(K,0Rux) = A(K,0GLUM)
53: A(K,0CGLUM) = SWAP
54: 705 CENTINCE
55: 740 CENTINCE
55: 740 CENTINCE
55: 740 CENTINCE
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MOTOROLA INC SCOTTSDALE ARIZ GOVERNMENT ELECTRONICS DIV LRPDS INTERIM TECHNICAL REPORT. APPENDICES, (U) AU-AU47 145 F/G 17/3 JUN 71 S ATTWOOD DAAK02-71-C-0022 NL UNCLASSIFIED 2 of 4 ADA047145



CLARKE 1866 A = 6,378,206.4 M 1/F = 294.978698 CENTRAL SCALE FALIDE = .9996

DUTHING	METERS	3754702-1723	39+00000•0014	3849999993	37+0000-0001	2706279 1748	9328895.5101	37/5132-6198	37/5092-7274	18881458 • 4577	2388460.8581	93<7985.0788	-	5868069.0794	5073145.0959	1904192-9796	89<0733 • 1898	14310544.2947	0000.	3578068 • 9357	3706121.9902
EAST14G	YETERS	772075-8124	7200000083	7200000024	720000-0069	298150 • 5076	534996•3300	631555 1610	631557 - 7170	502064.5275	•	•	463589.9772	448757 • 0142	621374•3637	774/55-8815	556134 1448	433747•9025	50000.0000	719221 • 9445	406279•6840
	OIM ZENE	14	14	14	14	36	36	10	12	NO.	23	19	14	10	ŋ	17	**	-	31	11	12
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LATI TUDE	SFC	34 - / 420	51.5020	48.4967	24+0-44	3000	00000	37.8300	30.5340	00000	00000	00000	31./854	7.8531	59.1456	25.8631	20.0000	35.5478	• 0000	00000	32.0863
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	METERS	METERS		^	2	SEC	2	Σ	275
12	476279 8000	3706122.0000		(5)	53	32.0827	-115	၁	31.8772
15	406290 • COCO	3706085.0000		(Y)	53	30.4846	-115	၁	31.4681
12	631555 1600	3775132-6200		7	9	3/•8300	601-	34	25.2340
15	631543.6220	3775276-2120		75	•	42.4960	€01-	34	25.6060
15	631557 • 6800	3775093-1360		7	Q	36.5473	-109	75	27:1:42
12	631577-7480	3775093.189u		40	•	36.5399	601-	34	24.3741
14	720000-0000	3940000.0000		35	34	51.9020	• 96	34	19.5155
7.4	720000.0000	38400000000		4	40	48.4967	96 -	32	55.3153
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13	255165.4500	3994009-5400		36	m	42.0541	10t-	6	5.7720
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11	719221.9400	3598068.9400		32	30	.0001	-114	40	500D•
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12	406279-6840	3706121.9902		33	63	32.0823	-115	0	31.8817

CLARKE 1866 A = 6,378,206.4 M 1/F = 294.978698 CENTRAL SCALE FALIUR = .3996

LOCAL MEFERENCE

LANGITUDE D M SEC	55.3123	2 SHETEMS	220-8282	997 • 0027	191 • 9368	-993-0480	606.4633	793.9254	2572.0146	2702 • 2695	7 1130	112.2100	1940.3129	3203.9408	133.2032	454 - 7438	1000.0000	100.0000	*553·63U4	5241.31.57	972.5340	-700.5925
	48.4967 - 96 35	Y METERS	975.0881	4878.3287	542510+114	113102-1126	-39512-0714	20148-4637	41923.0310	4994V • 5003	79697 • +850	8370-7637	-19970-3467	1835.4315	-64475-4743	738 • + +26	*7758	0000.	-89931-1306	-7836-3495	-262.3749	-100948-4157
LAIITJUE U M SEC	34 40 48	X ME TEAS	1023-3934	511/.5887	31304 • 7243	17727.4425	-20343-4575	-6019-6153	-79054-8141	3199.6741	12920-4319	68195.3092	40536.0246	-34979-9923	-22531 • 4620	-30989-5859	1.0235	- 00000	•31E3•9758	34841.4816	10995-9496	•2381 • U682
NBRIHING	3840000.0000	ELEVAT19N METERS	221.0000	1001-0000	501.0000	488.0000	763.0000	829.0000	3200.0000	2900.0062	521 • 0000	482.0000	2100.0000	3300.0000	499.0030	500.0000	1000.0000	100.0000	82.0000	5341 - 0000	986.0000	100.0000
EASTING METERS	720000-0000	NONTHING METERS	3841000.0000	3845000.0000	3895000.000888	39550000000000	380000000088	3850000-000088	3880000.0000888	3890-00-0688	3920000-0000	345000000000000000000000000000000000000	3821000.0000	3841000.0000	3775000.0000	3839399•0000	3840001-0000	3840,000	3/20-00-036/8	383300.0000	384000000000	3/3900000000
G NE	1	EASTING METEKS	721000.0000	725000 • 0000	15000.000004	795000 • 0000	70000000000	713500.0000	0000-0000+9	722000-0000	731000.0000	788000.0000	761000-0000	6850C0 • 00C0	0000 • 000669	0220.0000489	720001-0000	720000 • 0000	719000.0000	755000.0000	731960 • 0060	720000-0000
UTM ZUNE	-	UTM ZBVE	14	14	4 B-	÷1 6	3 1 4 8	14	1.4	14	4	14	74	14	14	14	14	71	7,1	14	14	14

.

1/F = 294.978698 CLARKE 1866 A = 6.378,206.4 M CENTRAL SCALE FALIDIA = .5996

11

LUCAL REFERENCE

TUDE LANGITUDE SEC	48.4967 - 96 35 55.5123	NORTHING ELEVALION METERS	340994•4945 SET.	3844999• 1999	, ")	3953560.+037		3859994 - 3998 823 - 0000		3889999•3995	3919999.4991				3775000 - JJ11		38400000-3979	3840000		3833000•0000	384000000000	
LATITUDE 5	34 46	EASTING METERS	720999 • 9954	725000 • 0000	148999.9994	252076 - 2362	99999	713500 • 0000	640000.0008	722000-0000	730999 • 9996	238750 1656	761000 • 0009	9666 • 666 + 89	0666 • 666869	688999 9997	720001 • 0025	720000 . 0000	718399 • 9998	755000.000467	1300.	
NURTHING	3840000•0000	UTM ZONE	14	14	14	15	7.7	14	14	14	77	15	14	7 7	7	7 7	14	† • • • • • • • • • • • • • • • • • • •	4	14	14	
		Z METERS	220 • 8262	97.002	191.9368	-993-0480	606 • 4633	793.9254	2572.0146	2/02 • 2695	7.1130	112.2100	1940.3129	3203.9408	133.2032	24.	1000-0000	100.0000	-553-6304	5241.3137	972-5320	
EAST. METE	727000-0000	Y METERS	9/5-6881	323	54251-4114	113102-1125	-39512·J/14	20148-4537	41923-5310	49945 · 3003	19697 • 4655	83/0.0637	-19970-3467	1835-4315	-644/8.4/43	738 • 4+26	94/6.	0000	-89931 • 1306	-7836.3495	-262.3/49	
UTM ZÜNE	14	ME TERS	1023+3934	5117-588/	31304.7243	77721.4425	20943.4272	-6019-6153	-79054 - 8141	3199•6741	12920 • 4319	68195 3092	40536-0246	-34979 • 9923	*22531 • 4620	30989 5555	1 • 0235	0000 -	-3123-9758	34841.4816	10995 9 496	

APPENDIX C PROPAGATION CORRECTIONS

1. INTRODUCTION

The propagation correction procedure discussed in this appendix is a simplified version of that reported in the LRPDS Error Analysis dated 15 April 1971. The procedure is simplified to the degree that each of the 1800 possible range measurements made during a flight can be corrected individually if desired. Certain simplifying assumptions are discussed in the following paragraphs that allow the above conclusion to be made.

The National Bureau of Standard at Boulder, Colorado recommends (reference one) the use of a bi-exponential model for the refractivity of the atmosphere,

$$N(h) = D_{s} e^{-\delta} \binom{h-h}{m} + W_{s} e^{-\omega} \binom{h-h}{m}$$
 (1)

in which the first term is referred to as the "dry term", and the second is called the "wet term". In equation (1), h_m is the surface altitude in km above mean sea level at which the coefficients D_8 and W_8 are measured; the latter are determined from the Smith and Weintraub constants (reference two),

$$D_{g} = 77.6 \frac{P}{T}$$

$$W_{g} = 3.73 \times 10^{5} \frac{e}{T^{2}}$$
(2)

where P is the total atmospheric pressure in mb, T is the absolute dry bulb temperature (°K) and e is the partial pressure of water vapor in mb. The partial pressure of water vapor may be obtained from the psychrometric formula (reference two)

$$e = e_g' - P(T-T') (471 + 0.665) \times 10^{-6}$$
 (3)

where e_8' denotes the saturation vapor pressure in mb at the absolute wet-bulb tempterature, T'. It is assumed in this discussion that the measurements required to make an accurate determination of D_8 and W_8 will be available.

It is further assumed that reasonable estimates for the values of the dry and wet terms in the vicinity of the aircraft altitude can be made; from this information, the scale factors δ and ω in equation (1) can be determined as

$$\delta = \frac{\ln[D_8/D(h)]}{(h-h_m)}$$
and $\omega = \frac{\ln[W_8/W(h)]}{(h-h_m)}$
(4)

Given that the atmospheric refraction is modeled as a bi-exponential, what are the residual propagation errors caused by modeling errors? This question is answered in reference three. In that study, both horizontal and vertical refractive gradients were assumed and the effects on the value of the range correction were determined; the horizontal gradients were approximately 60 Numits per 80 km. The NBS people at Boulder suggest that this represents the worst case situation for typical locations around the globe. As many as five different vertical profiles were inserted into a computer program that evaluated the actual refractivity along each ray path between an aircraft at 6 km altitude and FO's located at various points on the ground. Assuming that this atmosphere could be represented in bi-exponential form, with the parameters in equation (1) known via two measurements, one made on the ground and one made at the aircraft altitude, the results showed that the rms variation in the range correction due to horizontal gradients was about 1 part in 10⁵.

However, the above assumes that a measurement would be available in the aircraft; no such measurement will be available in the field. Reference four showed that if the refractivity at the aircraft (or any other arbitrary) altitude is estimated, rather than measured, then the loss in accuracy is about 1 part in 10⁵ for every 10% error in the estimate. This error proves to be the dominant, residual error assuming that the surface measurement of refractivity is good to within 5% (typical radiosonde measurements are better than this).

CORRECTION PROCEDURE

It has been shown that the atmospheric refractivity can be modeled, with sufficient accuracy, as a bi-exponential. A sufficiently simple procedure to obtain the actual range correction is next described.

The effects of an inhomogeneous atmosphere were examined in reference three; there it was shown that inhomogeneities in the refractivity were averaged over the ray path. Specifically, large refractive gradients (including surface ducts) had very little effect on the range correction required; the range correction was sensitive to only the average index of refraction, \overline{n} . Therefore, a simplified procedure requires a means of determining \overline{n} . Assume the typical propagation geometry of Figure C-1.

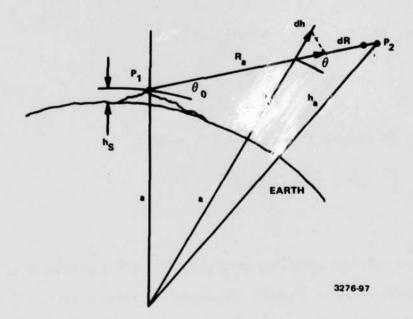


Figure C-1. Typical propagation geometry for which h_g in the surface altitude above sea-level, a is the earth's radius, θ_0 is the geometric angle of elevation, and θ is the angle between the ray P_1P_2 and the normal to the radius a + h.

It is seen that the actual path length, R_a , between points P_1 and P_2 is given by

$$R_{\alpha} = \overline{c}\Delta T$$

where \overline{c} is the average propagation velocity and ΔT is the existing time delay. However, $\overline{c} = c_o / \overline{n}$ where c_o is the propagation velocity in a vacuum and \overline{n} is the average refraction index. Therefore

$$R_a = \frac{c_o}{\overline{n}} \Delta T = \frac{1}{\overline{n}} R_m ,$$

where R_m is the "measured" range. By definition, the range correction is the difference between the measured and actual ranges.

$$\Delta R = R_m - R_a$$

$$= (\overline{n-1}) R_a$$

$$= (\overline{n-1}) R_m$$
(5)

By definition, the average index is given by*

$$\overline{n} = \frac{1}{R_a} \int_{P_1}^{P_2} N(R) dR \tag{6}$$

along the ray it is seen that $dh = dR \sin \theta$, so

$$\frac{1}{n} = \frac{1}{R_a} \int_{h_s}^{h_a} \frac{[1 + N(h) \cdot 10^{-6}]}{\sin \theta} dh$$
(7)

^{*}It is assumed that the geometric path P_1P_2 does not appreciably differ from the actual path which is slightly curved due to refractivity. It has been shown that these two paths differ in length by only centimeters for typical applications; consequently, the expression in equation (6) is essentially correct.

where $n(h) = 1 + N(h) \cdot 10^{-6}$; N(h) is given by eqn (1) and is measured in N-units. Breaking the two integrals into two integrals,

$$\frac{1}{n} = \frac{1}{R_a} \int_{R_a}^{h_a} \frac{dh}{\sin \theta} + \frac{10^{-6}}{R_a} \int_{R_a}^{h_a} \frac{N(h)dh}{\sin \theta} , \qquad (8)$$

it is seen that the first integral is first equal to R_a . Therefore, eq (8) becomes

$$\overline{n} - 1 = \frac{10^{-6}}{R_a} \int_{h_a}^{h_a} \frac{N(h)dh}{\sin \theta}$$
(9)

It has been found that the average refractivity given by eqn (9) is remarkably insensitive to changes in θ . For instance, assuming a typical exponential profile for the atmosphere, and an aircraft altitude of 6 km, then the average refractivity, \mathbb{N} , is 244 N-units for a slant range of 10 km to the ground, 249 N-units at 100 km, and 255 N-units at 150 km; this error is a bias amounting to not more than 1 part in 10^5 over the ranges of interest. Therefore, eqn (9) may be calculated just once at some arbitrary θ , and the resulting \overline{n} used for all ranges. The value of θ that leads to the simplest implimentation is 90° in which case R_a is equal to $h_a - h_8$. With these simplifications, and using eqn (1), eqn (9) can be integrated easily to obtain

$$\overline{n} - 1 = \frac{10^{-6}}{(h_a - h_s)} \left[\frac{D_s e^{\delta h_m}}{\delta} \left(e^{-\delta h_s} - e^{-\delta h_a} \right) + \frac{W_s e^{\omega h_m}}{\omega} \left(e^{-\omega h_s} - e^{-\omega h_a} \right) \right]$$
(10)

It is noted that all of the parameters in eqn (10) are readily determined (or assumed known) except for h_a and h_s . These two parameters can be determined from the data reduction process in the system computer. After the first two or three passes in the data reduction computer program, the x, y, z coordinates for each aircraft and ground station position is known relative to a plane, the origin of which is located at some altitude Z_o relative to sea level. The geometry is shown in Figure C-2.

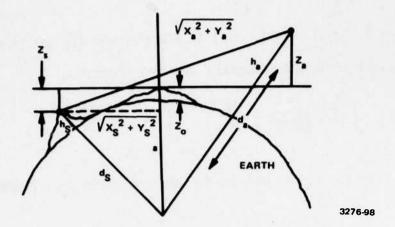


Figure C-2. Cross-section of earth showing coordinates of aircraft and ground station relative to a plane, the origin of which is located at an altitude of Z_O above sea level.

It is seen that

$$h_{\alpha} = d_{\alpha} - a$$

and
$$d_a^2 = (\sqrt{X_a^2 + Y_a^2})^2 + (Z_a + Z_o + a)^2$$

Likewise, (11)

$$h_{s} = d_{s} - a$$
and $d_{s}^{2} = (\sqrt{X_{s}^{2} + Y_{s}^{2}})^{2} + (Z_{s} + Z_{o} + a)^{2}$

Eqns (11) must be calculated once and stored for each aircraft position and each ground station location; this requires only 50 to 70 computer words plus the storage of \mathbf{Z}_{o} and a.

With the calculations of eqn (11) completed, the average index is found immediately from eqn (10), and each range correction is found using eqn (5). SUMMARY

The correction procedure described above is exceedingly easy to apply. The following steps are required in the computer program:

- 1. After the ground station and aircraft positions are correctly determined (except for propagation errors), eqns (11) are solved for each h_a and h_s and stored.
- 2. For each R(J, K) in the computer program, eqn (10) is solved for π 1.
- 3. The range correction is determined using eqn (5).
- 4. Each range correction is subtracted from each R(J, K) to obtain the true range.
- 5. Another pass in the data reduction process is initiated to determine the true aircraft and ground station positions.

The over-all accuracy of the range correction procedure has been shown to be approximately two parts in 10^5 with good radiosonde data (1 part in 10^5 error due to modeling errors, and 1 part in 10^5 error due to the approximation in \overline{n}). If the refractivity at some arbitrary altitude must be estimated, then an error of 1 part in 10^5 for each 10^8 error in the estimation will also be present.

REFERENCES

- B. R. Bean, et al, "A World Atlas of Atmospheric Radio Refractivity", U.S. Department of Commerce Environmental Science Services Administration, Monograph 1, 1966.
- 2. B. R. Bean, E. J. Dutton, "Radio Meteorology", National Bureau of Standards Monograph 92, March 1, 1966.
- 3. E. J. Carlson, "Residual Propagation Errors Caused by Atmospheric Modeling Errors", TM #M-108, Systems Analysis Group, Motorola, Inc., February 15, 1971.
- E. J. Carlson, "Implementation of Propagation Corrections Procedures for L.R.P.D.S.", TM #M-109, Systems Analysis Group, Motorola, Inc., March 3, 1971.

Appendix D

Scientific Field Data Reduction Program

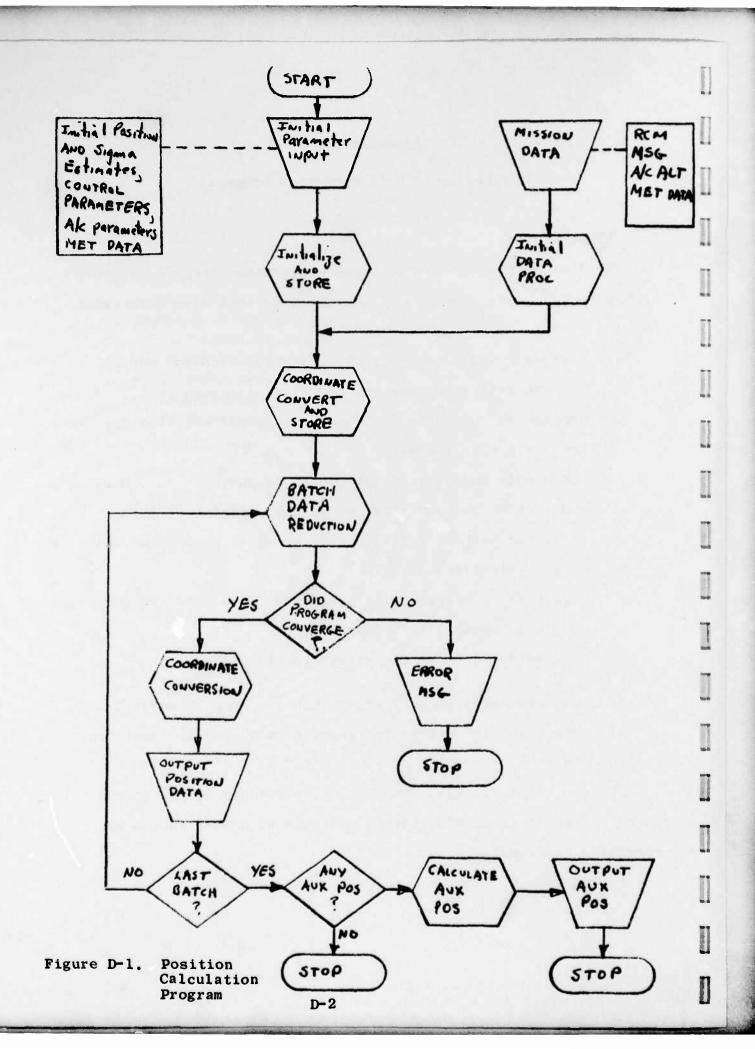
1.0 INTRODUCTION

The flow diagram of the position calculation program is shown in Figure D-1. The program may be separated into five major tasks namely:

- a. Parameter and data input which is processed to provide program control parameters and initialization data.
- b. Coordinate conversion to change all input position data to local XYZ coordinates.
- c. Batch data reduction which separates the data into batches and locates the local XYZ coordinates of the position reference set and position sets along with an error analysis of the calculated position.
- d. Coordinate conversion to change the calculated XYZ coordinates into geographic lat-long or UTM.
- e. Calculate any desired auxiliary positions.

The required input data is taken from the mission derived tape containing mission initialization and raw data from the position reference set.

Program initialization data may be overridden by input data cards. Also, program flow may be modified by proper choice of control parameters.



2.0 PARAMETER AND DATA INPUT

In order to initialize the data reduction program certain input data is required. The input tape will provide

- a. Initial position set position estimates in either lat-long or UTM coordinates plus altitude in meters.
- b. One sigma position estimates of location error in meters.
- c. Flight parameters such as turning points or actual position estimates and max velocity.
- d. Number of position sets.
- e. Meterological data for propagation correction.
- f. Raw data received from the position reference sets.

Proper arrays are set up in global memory to contain this information so that it can be accessed by the various data processing routines. The raw data is unpacked and stored in arrays according to category such as aircraft altitude, time tags, lost lock flags, meterological data, auxiliary point data, message data and range change data. Before storing the range change data, the coarse and fine words are combined and normalized into one 32 bit floating point word.

3.0 COORDINATE CONVERSION

All position input information is changed into local XYZ coordinates. This includes the initial position set estimates as well as all required aircraft initialization positions that may be called out by the program. The coordinate conversion is described fully in Appendix B.

4.0 BATCH DATA REDUCTION

The flow diagram for the Batch Data reduction is given in Figure D-2 pages 1 through 8, with a detailed flow diagram of the Subroutine REDUCE shown in Figure D-3 pages 1 thru 7. This is the major part of the data reduction task.

4.1 FLOW DIAGRAM DESCRIPTION

The input range change numbers represent one way propagation time differences from the initial measurement. These numbers are examined for blanks representing data drop outs and parity errors. This information is utilized along with the lost lock flag data to arrive at a lost data matrix where 1 represents a good data point and 0 indicates a blank data point. All bad data is set to zero value. The data point preceding a lost lock flag is considered bad in arriving at the lost data matrix.

A test of the lost data matrix is made to determine the maximum number of aircraft location positions KMAX. The data is compacted to close up any blanks created by deletion of aircraft positions not satisfying the minimum station visibility criteria. An average propagation correction factor is utilized to arrive at an average propagation velocity. This velocity is used to scale the range change times to range change distances in meters. The time tag vector is converted to real time utilizing the input A/C times versus time tag number. The range change measurements are tested against a maximum number derived from multiplying the aircraft velocity times the measurement time difference. Any range change distances (RCM) exceeding this maximum are deleted and the lost data matrix and KMAX updated to include this deletion.

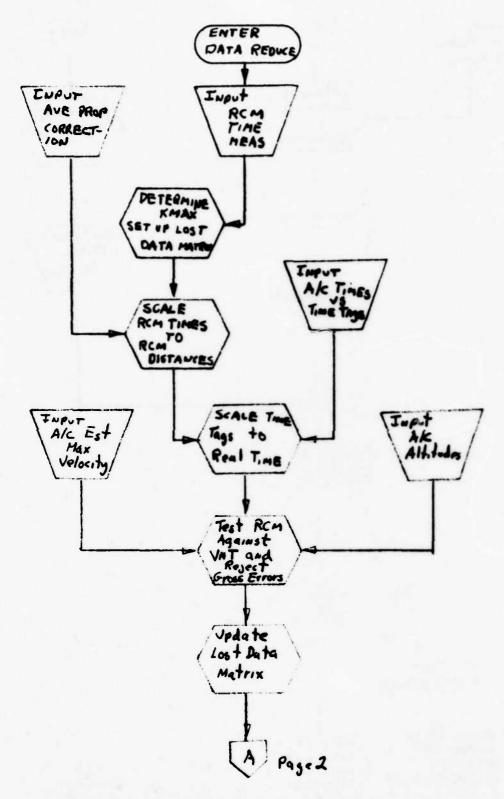
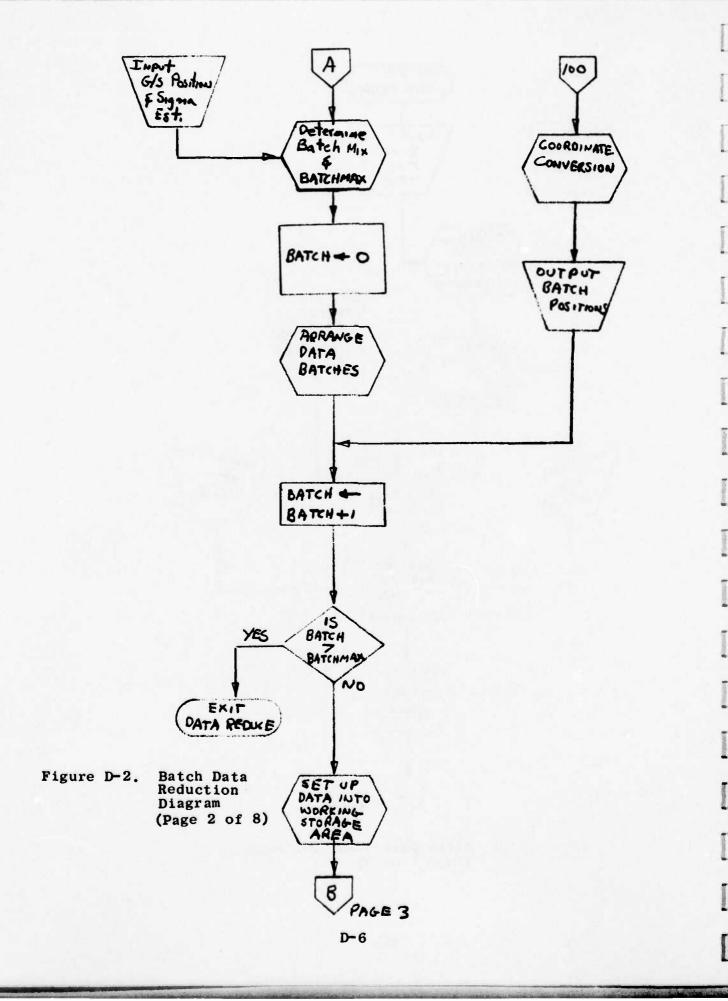


Figure D-2. Batch Data Reduction Diagram (Page 1 of 8)



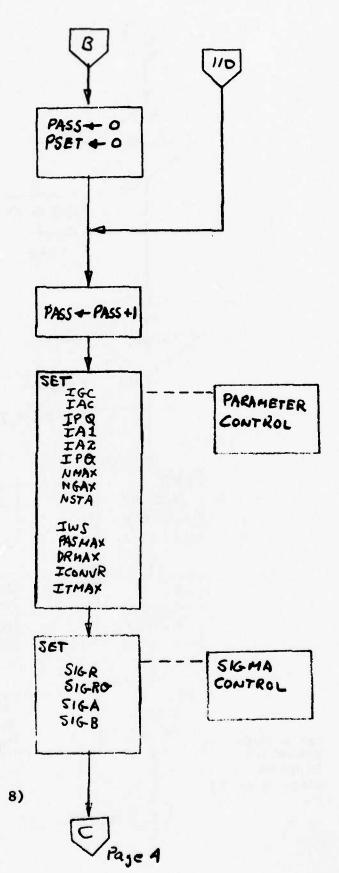


Figure D-2. Batch Data Reduction Diagram (Page 3 of 8)

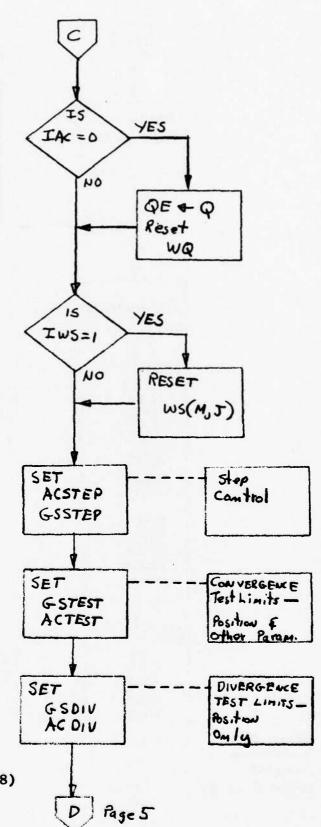
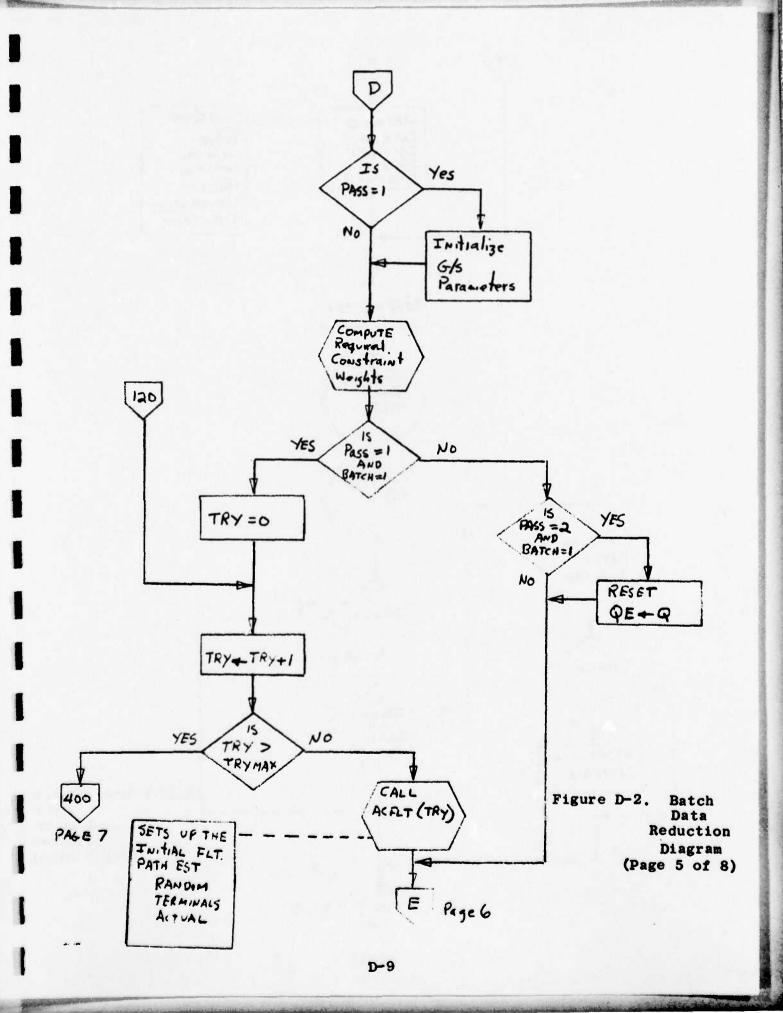
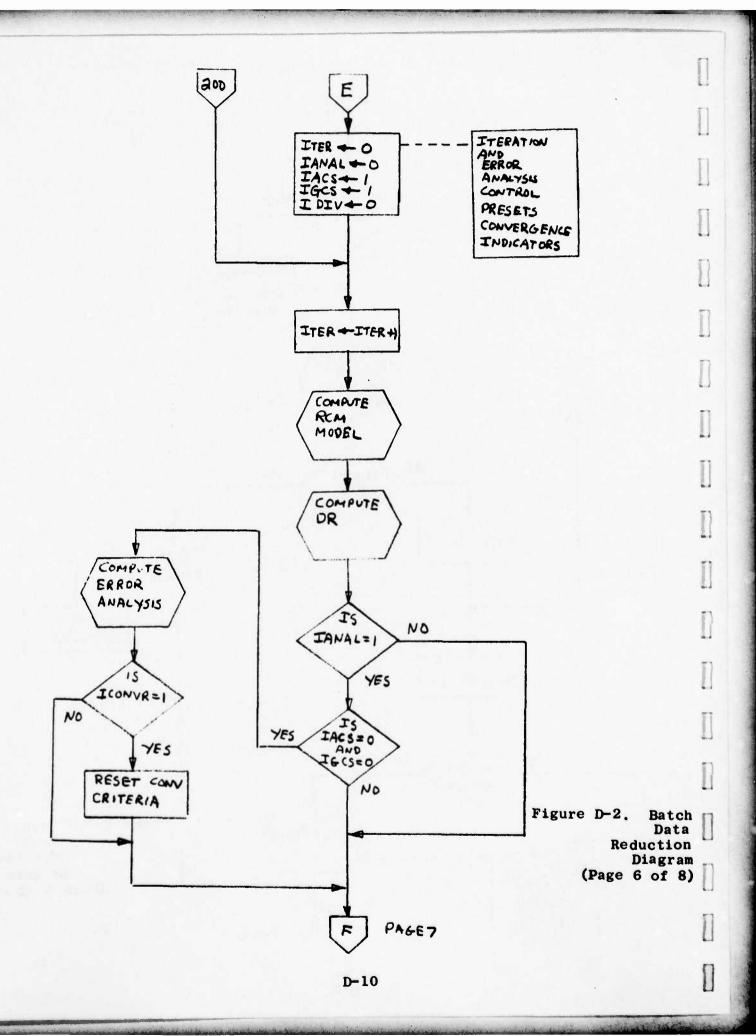


Figure D-2. Batch Data
Reduction
Diagram
(Page 4 of 8)





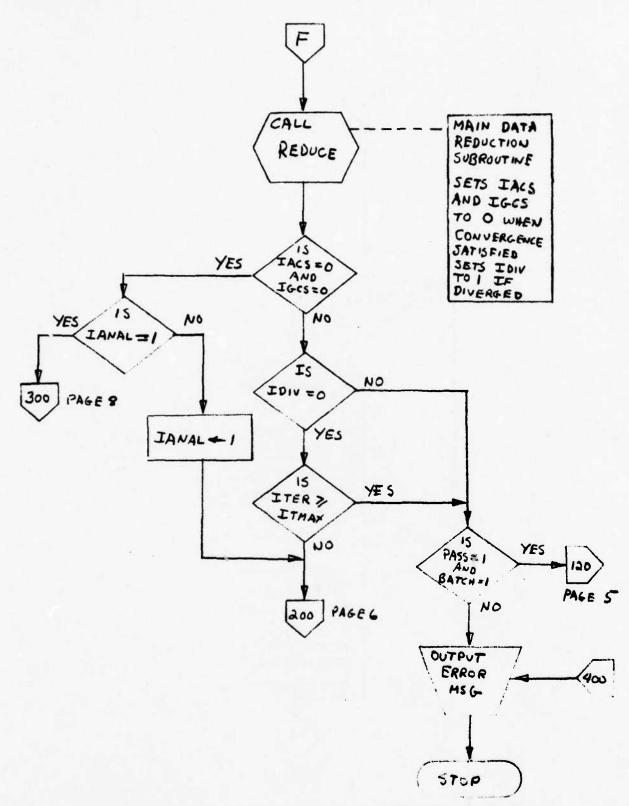


Figure D-2. Batch Data Reduction Diagram (Page 7 of 8)

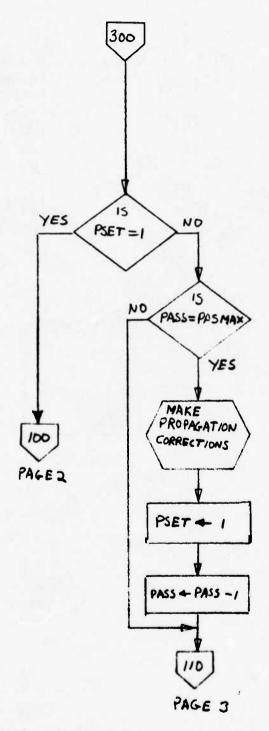


Figure D-2. Batch Data Reduction Diagram (Page 8 of 8)

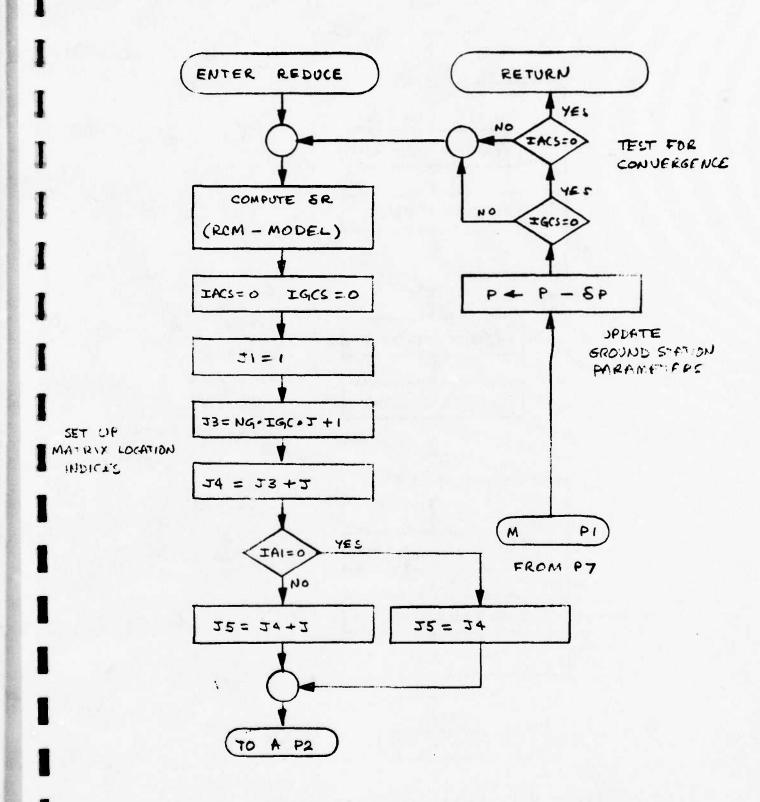


Figure D-3. Subroutine Reduce Diagram (Page 1 of 7)

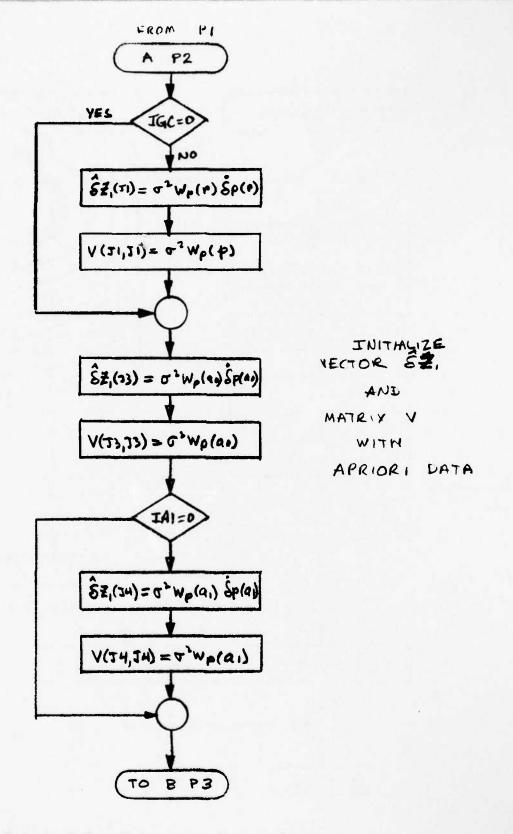


Figure D-3. Subroutine Reduce Diagram (Page 2 of 7)

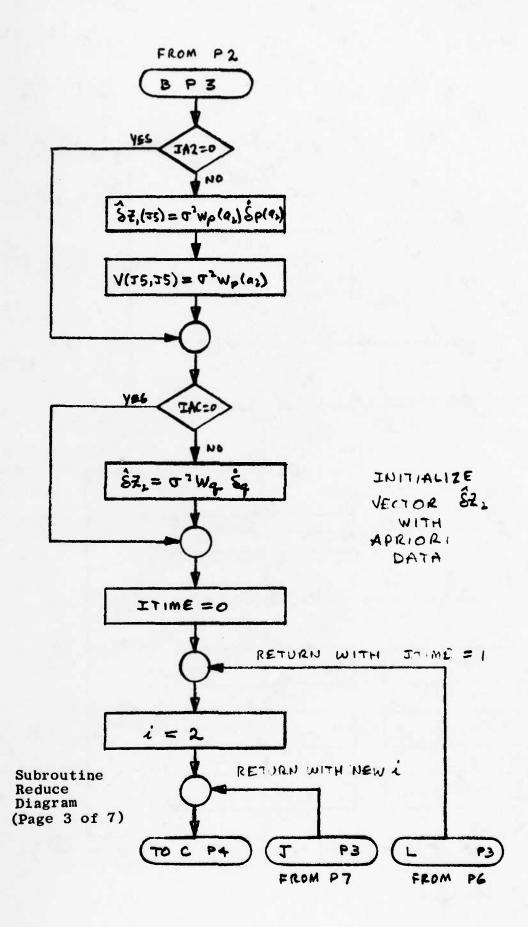
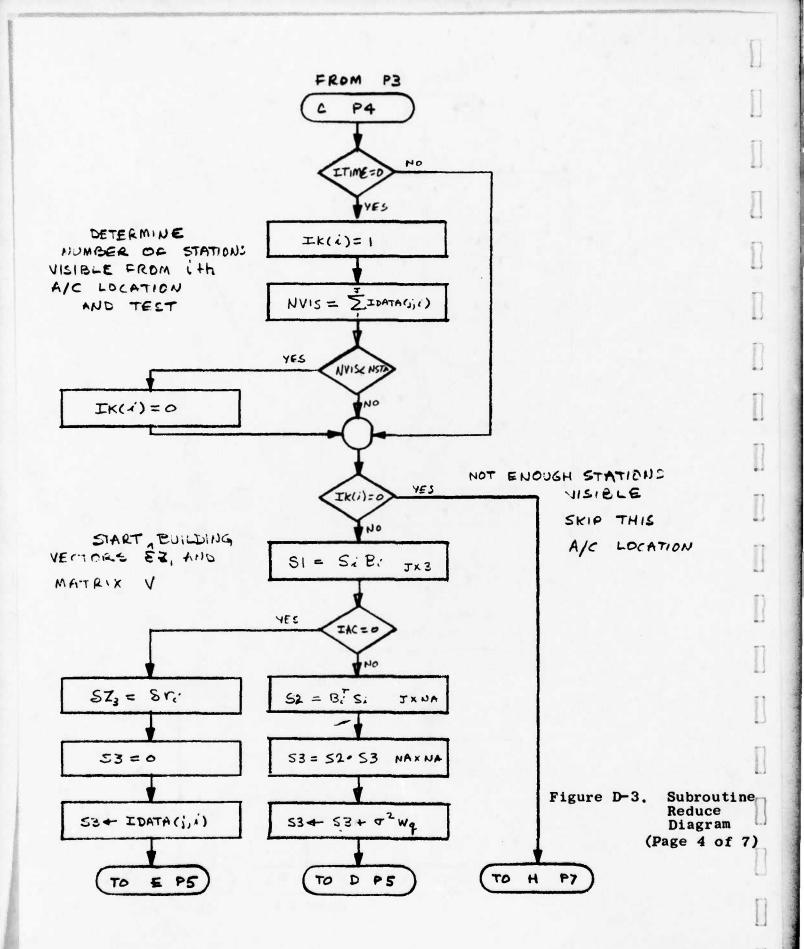
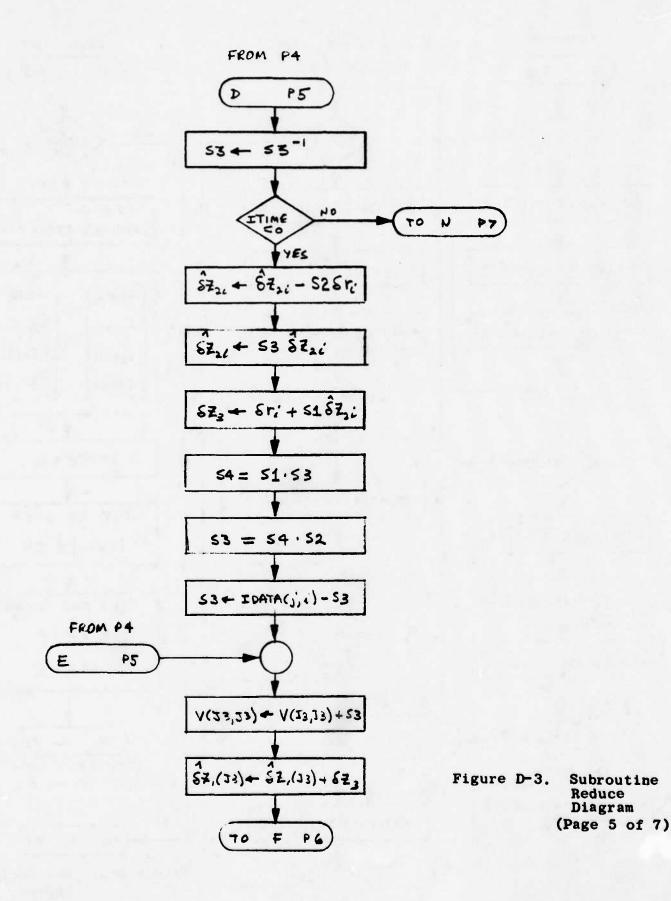
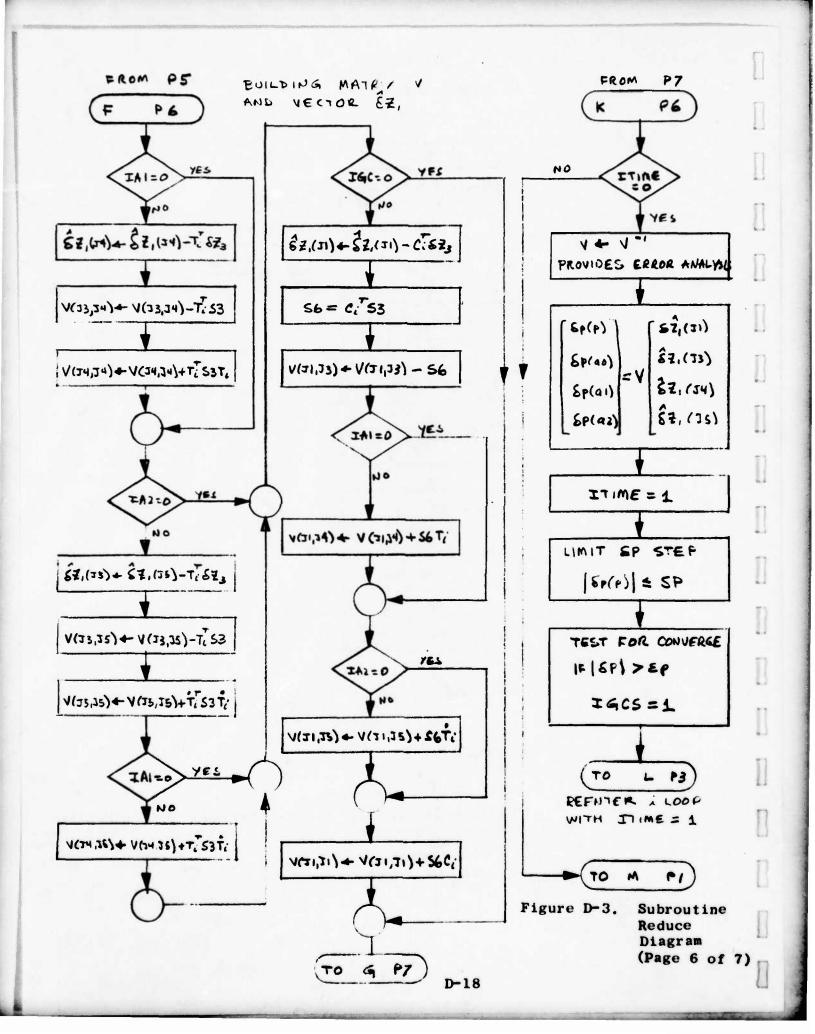
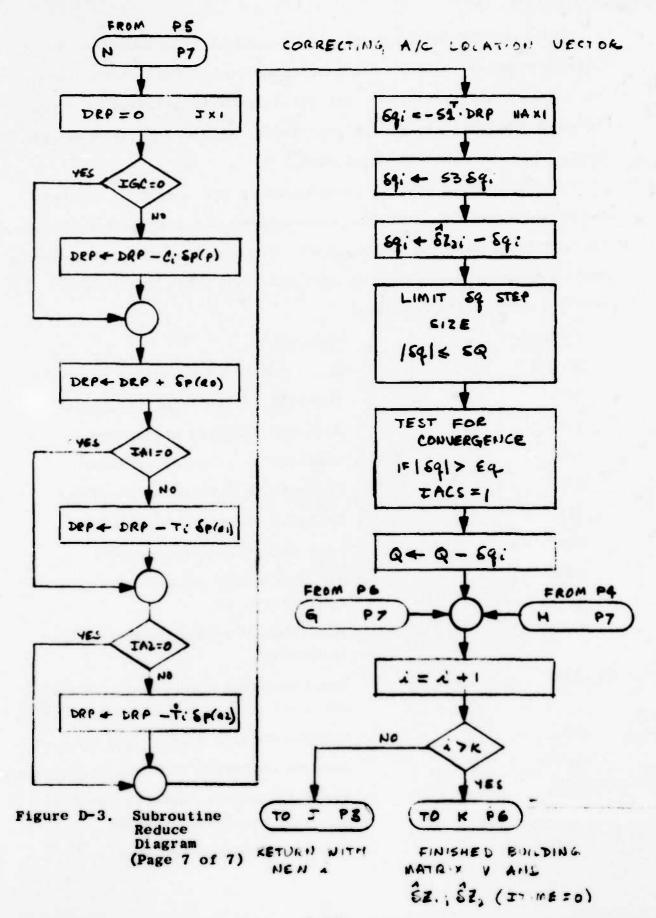


Figure D-3.









Utilizing the lost data matrix, ground station locations and position error estimates, the data reduction is partitioned into batches for data reduction. The first batch is selected by choosing the prime stations along with the closest geographically scattered locations having the most good data.

The batch input data is transferred to the reduction working storage area and the data pass control PASS and propagation correction indicator PSET are set to zero. PASS is incremented and the pass dependent program control variables are set. The integer program control variables are.

Variable	Control
BOGMAX	Bogus data edit iteration control
IGC	Position set location estimation
IAC	Aircraft location estimation
IPQ	Quantity of progress printout
IAl	Estimate PS oscillator frequency
IA2	Estimate PS oscillator drift
IPO	Pass dependent print control
NMAX	Aircraft number of dimensions
	estimated
NGAX	Position set number of dimensions
	estimated
NSTA	Required minimum number of ground
	stations visable at each A/C location
IWS	Unknown station sigma reset control
PASMAX	Maximum number of data reduction passes
DRMAX	Max diff between computed and actual
	RCM data bogus data editing
ICONVR	Reset convergence criteria

Variable	Control

IBOGIE Bogus data editing

ITMAX Maximum iterations of REDUCE without

convergence

The error estimates are set. These are as follows:

Variable

SIGR Range Measurement error

SIGRO Initial range est error

SIGA Initial freq est error

SIGB Initial freq drift est error.

A test is made on IAC and if aircraft positions are not being estimated, the aircraft estimated positions are set equal to the current locations. The parameter IWS controls resetting the position set variances. The maximum step sizes, convergence and divergence test limits are set and ground station parameters set if PASS = 1. The constraint weights are computed. On the first pass of the first batch, first try aircraft flight positions are placed in array Q and QE. On the second pass, the estimated positions QE is equated to the present computed position.

After aircraft initialization, the following control parameters are set.

ITER Iteration number

INAL Error analysis

IACS A/C convergence

IGCS PS convergence

IDIV REDUCE divergence

The iteration counter ITER is incremented and the range change model is computed. The error vector DR is computed from the difference between the range change measurements and computed range change values. The main data reduction subroutine is entered. Three control variables are set in this subroutine which control program flow upon exit from the routine. After first pass through REDUCE, with proper convergence the error analysis IANAL parameter is set to 1 which causes the error analysis to be computed. If ICONVR is set to 1, the convergence criteria may be reset before calling REDUCE a second time. With successful exit from REDUCE the bogus data control IBOGIE is tested. If bogus data editing is directed, this task is performed resetting last data matrix if required and reiterating through REDUCE. After successful data editing, a test of propagation correction control variable PSET and maximum pass PASMAX is made. If PASS is equal to PASMAX and PSET is equal to 0, the propagation correction is made and the program recycled thru the last pass to refine the positions. Successful convergence of REDUCE with no detected bogus data points causes the program to return to the beginning to pick up the next batch for processing. For all batches after the first batch, the aircraft positions are held fixed by setting IAC to 0.

4.2 SUBROUTINE REDUCE

The flow diagram of REDUCE is shown in Figure D-3 pages 1 through 7. For a detailed description of the process involved refer to Appendix A.

4.3 PROPAGATION CORRECTIONS

Appendix C details the propagation correction methods used in the program.

4.4 COORDINATE CONVERSION

The coordinate conversion routine is reentered to convert the local XYZ coordinates to Lat-Long and UTM before printing out the results of each batch.

5.0 AUXILIARY POSITION CALCULATION

After successful completion of the data reduction a test is made to determine if any aux positions are desired. If some positions are required, the position set location requesting the position is used as the origin of a local XYZ coordinate system. In other words the point X = 0, Y = - and Z = 0 correspond to the Lat-Long and Elevation of the PS location. The X Y Z of the AUX point is computed using the range, with elevation and azimuth angles as shown in Figure D-4.

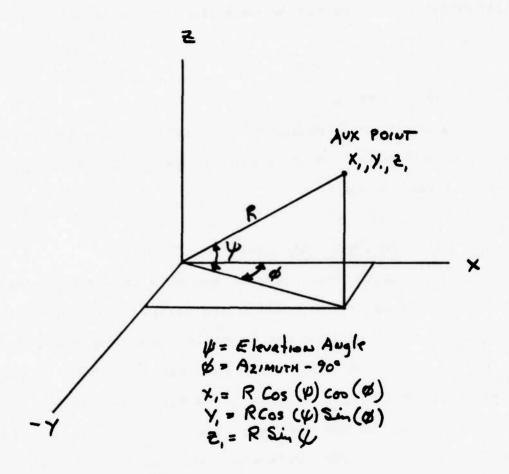


Figure D-4. Aux Point Local Coordinate Calculation

These local coordinates are then converted to Lat-Long or UTM by the coordinate conversion routine.

APPENDIX E

FIELD DATA REDUCTION PROGRAM

With the exception of operator controlled program flow and bogus data editing, the field data reduction program is the same as the scientific data reduction program described in Appendix D.

A detailed flow diagram of the field data reduction portion reflecting these modifications is shown in Figure E-1, pages 1 through 8.

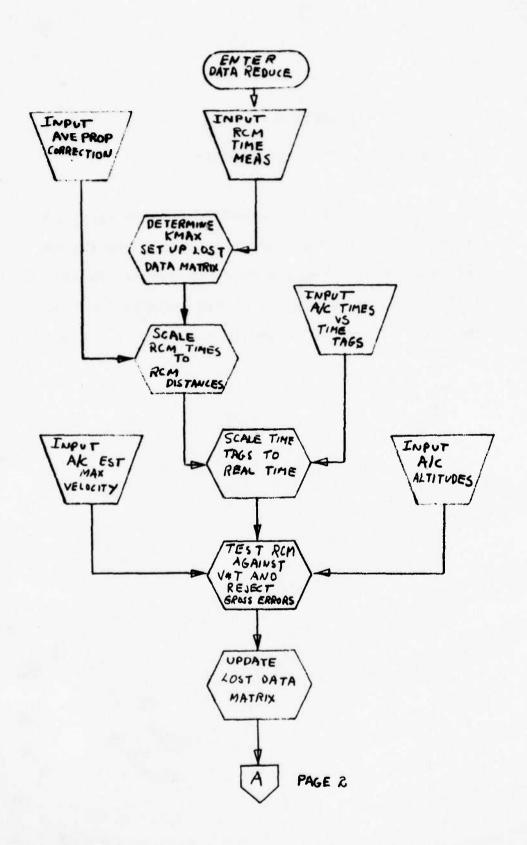
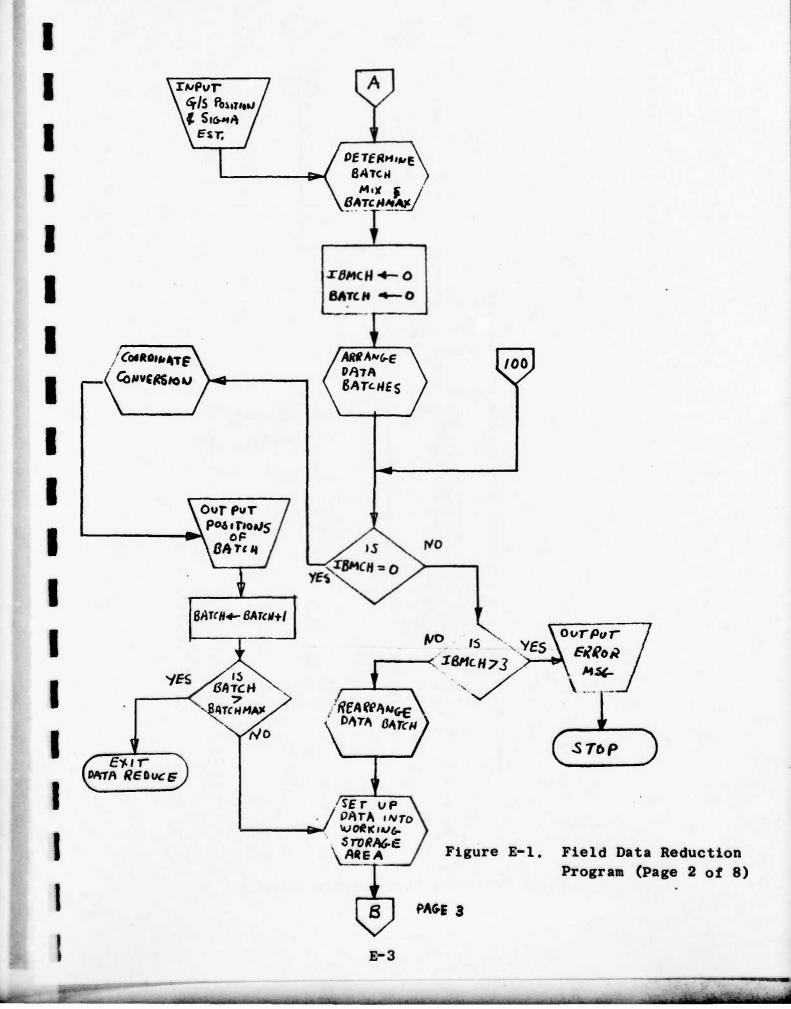


Figure E-1. Field Data Reduction Program (Page 1 of 8)



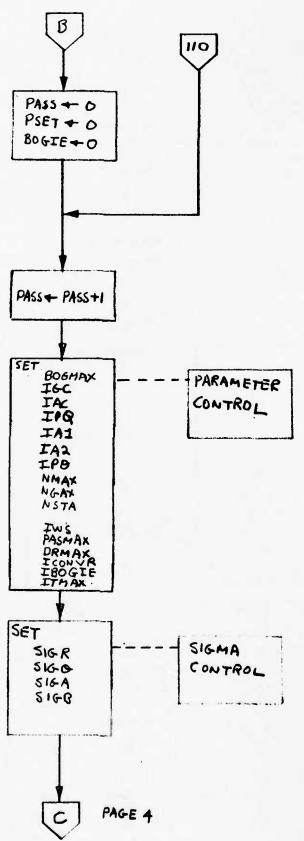


Figure E-1. Field Data Reduction Program (Page 3 of 8)

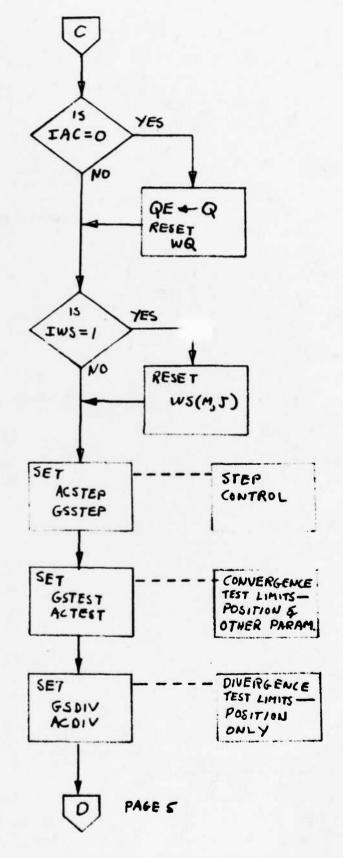
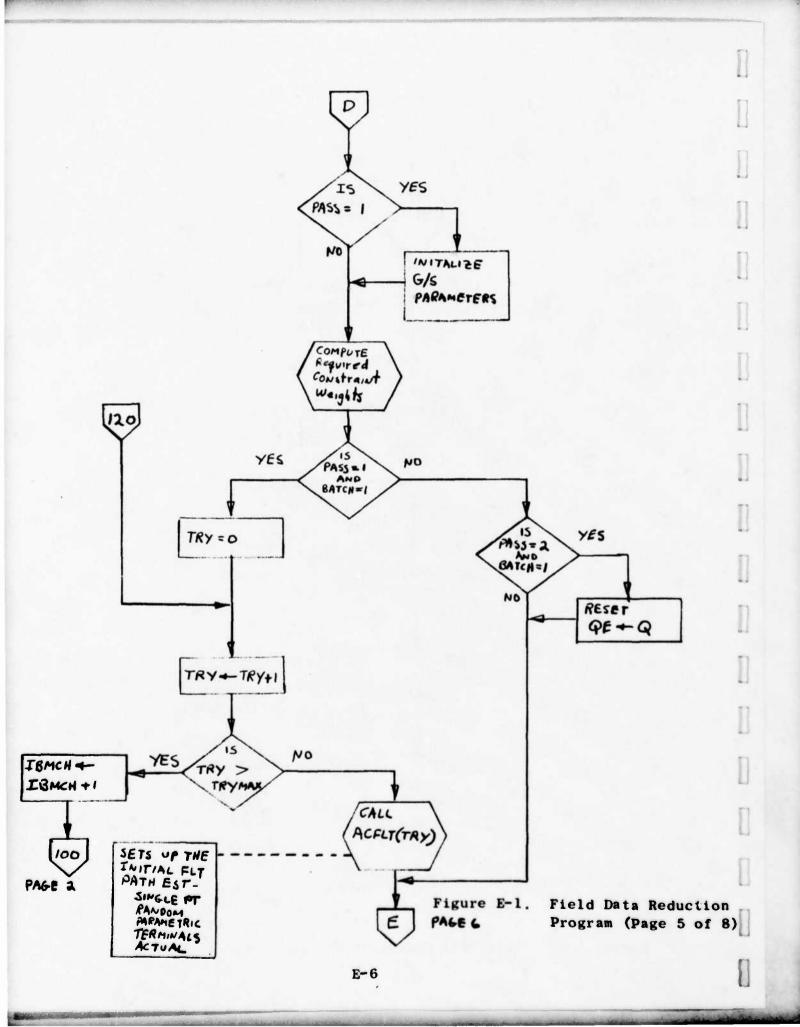
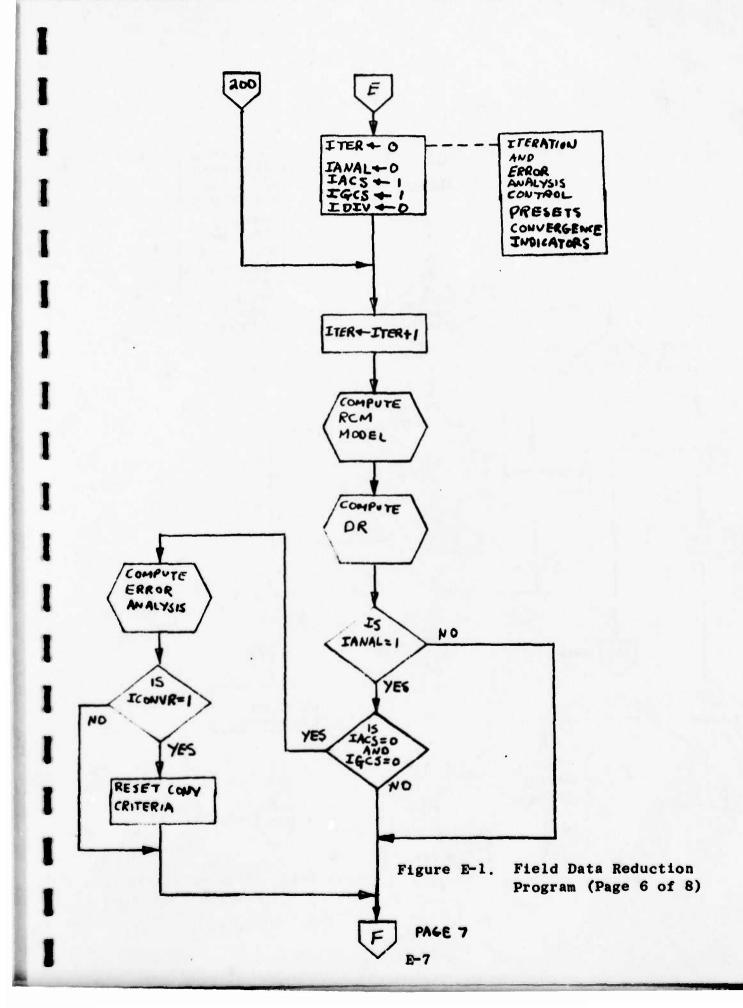
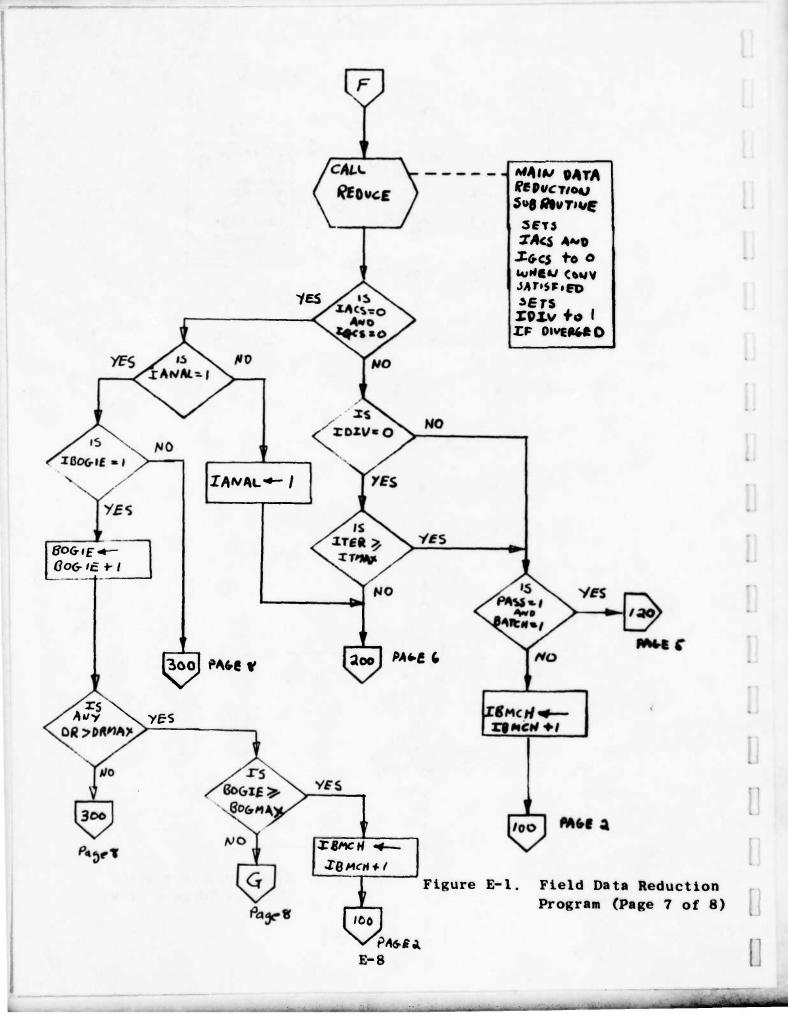


Figure E-1. Field Data Reduction Program (Page 4 of 8)







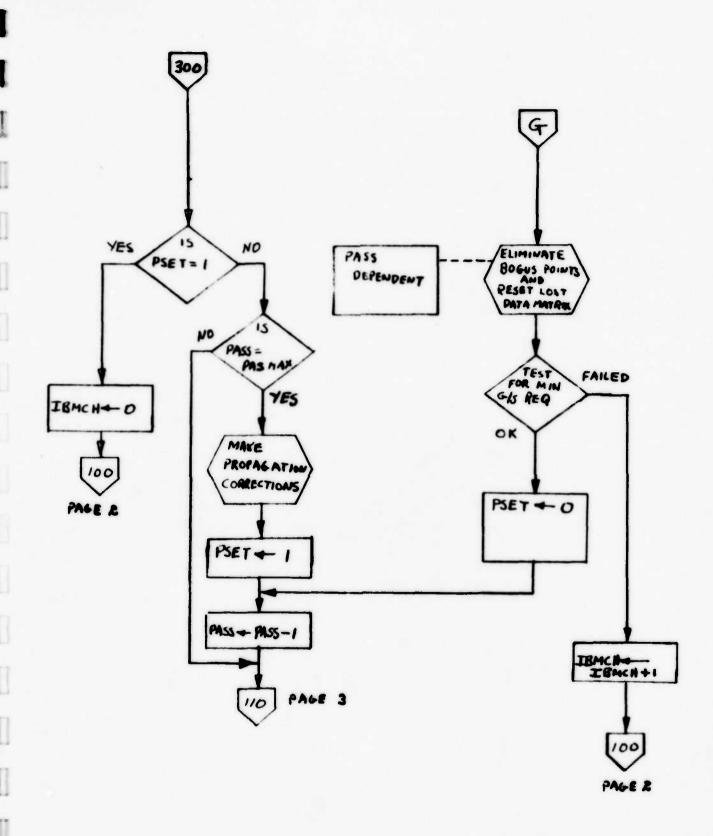


Figure E-1. Field Data Reduction Program (Page 8 of 8)"

APPENDIX F-1 .

LRPDS RELIABILITY MATHEMATICAL MODEL DEVELOPMENT

1. Assumptions

The following assumptions were applied in the development of the mathematical model.

- a. The system is a series system as described by the LRPDS Reliability Block Diagram (See section 10-2 of this report.)
- b. Operating times and duty cycles for each subsystem and unit used during a mission are as presented in Table F-1.2.
- c. Times to failure follow an exponential distribution.
- d. "Reliability" is defined as the probability that an item will operate without failure for the duration of the mission.

2. LRPDS Mission Time

The LRPDS consists of three subsystems, each of which operates for a different period of time during the mission. Furthermore, each subsystem is composed of units operating for different periods of time. Therefore, individual "mission" time has been developed for each subdivision of the system. These time elements are based on the "standard mission" as defined in paragraph 10.2.1 of this report, and are presented in the Reliability Block Diagram.

The operating times for each system subdivision were derived based on mission timing data developed during the LRPDS Mission Description study. The results of this study have been used to determine the approximate duration of each element of a "standard mission" (See table F-1.1.) These time elements are summed as appropriate to establish mission times for each unit of the system (See table F-1.2).

TABLE F-1.1
TIME ELEMENTS OF STANDARD MISSION

MISSION ELEMENT	TIME (Minutes)
Oscillator Warm-Up	
PS's and PCC/PS	240
A/C	120
Mission Initialization, etc.	
PCC	30
A/C	30
PS's	5
Initial A/C Position Run	7
Standby for P2 Command	5
Ranging Mission	46
Message Exchange	9
Data Processing & Reduction	15 *

^{*} Estimate of computer time required after completion of mission.

TABLE F-1.2
EQUIPMENT OPERATING TIME

**

SUBSYSTEM/EQUIPMENT	DUTY CYCLE	OPERATING TIME (HOURS)
PCC Subsystem		
Master Oscillator	1.00	5.9
PCC/PS (All except XMTR)	1.00	1.6
PCC/PS Transmitter	.03	1.6
All other PCC Units	1.00	1.9
Reference Position Subsystem (A/C)		
Rubidium Frequency Standard	1.00	3.5
Transmitter	.75	1.6
All other A/C Units	1.00	1.6
Positioning Set Subsystem		
Master Oscillators	1.00	5.2
Transmitters	.02	1.2
All other PS Units	1.00	1.2

In addition, operating duty cycles were determined for those items (transmitter) that are operated intermittently. These are based on the approximate time required to transmit each of the various commands and messages associated with the standard mission.

3. Basic Reliability Model

The reliability of a system composed of a number of elements connected in series (i.e., a failure in anyone of the elements causes a system failure) is given by the expression:

$$R_{s(T)} = \iint_{i=1}^{N} R_{i(ti)}$$
 (1)

Where:

 $R_{s(T)}$ = the reliability of the system for mission time T.

R_{i(ti)} - the reliability of system element i for its mission.

time
$$t_i$$
 $t_i \leq T$

N = the number of elements in the system

This basic model can be expanded by considering an individual element of the system. Assuming the exponential distribution,

$$R_{(t)} = \exp \left[-\lambda t\right] \tag{2}$$

Where:

the failure rate of the system element under the operational and environmental conditions encountered during time period t. Expression (2) assumes that the environmental and operating conditions remain constant for the entire mission. In general, individual subsystems of the LRPDS can be assumed to operate in a constant environment for the duration of the mission. However, certain system elements, in particular transmitters, will be cycled on and off during the mission. Assuming the failure rate of an item during operation is different than during periods of non-operation in the same environment, expression (2) can be modified:

$$R_{(t)} = \exp\left\{-\left[\lambda_{o}(t\cdot(d/c)) + \lambda_{n-o}(t\cdot(1-d/c))\right]\right\}$$
(3)

Where:

d/c = the duty cycle of the time, where duty cycle is the ratio of operating time to total time.

 λ_0 - the operating failure rate

),n-o = the non-operating failure rate

Failure rates are normally determined under operating conditions and non-operating failure rates are not available in most cases.

Therefore, expression (3) is not readily useable. However, a number of non-operating or storage life studies have indicated that operating failure rates are at least 10 times greater than non-operating failure rates in the same environment. Therefore, for the purposes of this

One such study is reported in RADC-TR-67-307, "Dormant Operating and Storage Effects on Electronic Equipment and Part Reliability".

model, it will be assumed that $\lambda_{n-0} = .1 \lambda_0$, in which case, expression (3) becomes:

$$R_{(t)} = \exp \left\{-\left[\lambda t \cdot (d/c) + .1 \lambda t \cdot (1 - d/c)\right]\right\}$$

Where:

 λ = the operating failure rate.

Rearranging this expression gives:

$$R_{(t)} = \exp \left[-\lambda t \left(.9 \left(\frac{d}{c}\right) + .1\right)\right]$$
 (4)

Expression (4) is used as the basic elemental expression in the development of the LRPDS Reliability Model.

4. Detailed Model Development

The LRPDS Reliability Model is based on the reliability block diagram (Figures 10-1 through 10-7 of this report). The system is assumed to have the following configuration:

- a. One Position Computing Central (Block number 1000 of the block diagram).
- b. One Reference Position Set (Block #2000)
- c. 27 Positioning Sets (Block #3000), only 5 of which include a Data Display Unit (Block #3300).

From expression (1), the system reliability is expressed as:

$$R_{s}(5.9) = R_{1000}(5.9) \cdot R_{2000}(3.5) \cdot R_{3000}(5.2)$$
 (5)

The 4-digit numbers refer to block numbers of the reliability

block diagram, and the numbers in parentheses are the mission times, in hours, for the respective subsystem. $^{2}\cdot$

The expression R_{3000(5.2)} referes to the entire PS subsystem consisting of 27 Positioning Sets. Each of the subsystems reliabilities is expressed as the product of the reliabilities of the individual units of the subsystem. Individual factors of these expressions are then factored into more elemental subdivisions until the subsystem reliability can be expressed as the product of a set of exponential expressions each having the form of expression(4). This development for the three subsystems is described in the following paragraphs.

4.1 Position Computing Central Reliability Model:

$$R_{1000} = R_{1100} \cdot R_{1200} \cdot R_{1300} \cdot R_{1400}$$

(Note, block 1500 represents GFE and is not being considered in this interim report. Therefore, R_{1800} and R_{1900} is set equal to 1 in this model.)

R₁₂₂₀ can be expanded according to Figure 10-3, giving:

$$R_{1220} = R_{1221} \cdot R_{1222} \cdot R_{1223} \cdot R_{1224}$$

The PCC model has now been factored into the lowest terms possible at the present state of system definition. Each factor is now expressed

^{2.} This subscribing method will be continued without further explanation in the remainder of this appendix.

in the exponential form by substituting appropriate time and duty cycle values from Figures 10-2 and 10-3 in expression (4):

$$R_{1221} = \exp \left[-\lambda_{1221} (1.6 \times 1)\right] = \exp \left(-1.6 \lambda_{1221}\right)$$
 $R_{1222} = \exp \left\{-\lambda_{1222} [1.6 (.9 \times .03 + .1)]\right\} = \exp \left(-.2 \lambda_{1222}\right)$

$$R_{1223} = \exp(-1.6 \lambda_{1223})$$

$$R_{1220} = \exp(-5.9 \lambda_{1220})$$

$$R_{1300} = \exp(-1.9 \lambda_{1300})$$

$$R_{1400} = \exp(-1.9 \lambda_{1400})$$

$$R_{1500} = \exp(-5.9 \lambda_{1500})$$

$$R_{1230} = \exp(-5.9 \lambda_{1230})$$

Substituting these values in the expression for R_{1000} , collecting terms and simplying:

$$R_{1000} = \exp \left\{ - \left[1.6 \left(\lambda_{1221} + \lambda_{1223} \right) + .2 \lambda_{1222} + 5.9 \left(\lambda_{1220} + \lambda_{1224} + \lambda_{1500} \right) + \left[1.9 \left(\lambda_{1300} + \lambda_{1400} \right) \right] \right\}$$

4.2 Reference Position Set Reliability Model:

$$R_{2000} = R_{2100} \cdot R_{2200} \cdot R_{2300} \cdot R_{2400}$$

R₂₂₀₀ can be expanded according to Figure 10-5.

$$R_{2200} = R_{2210} \cdot R_{2220} \cdot R_{2230} \cdot R_{2240}$$
 $R_{2210} = R_{2211} \cdot R_{2212}$

Expressing each factor in the exponential form by substituting appropriate time and duty cycle values from Figures 10-4 and 10-5 in expression (4):

$$R_{2100} = \exp(-1.6 \lambda_{2100})$$

$$R_{2211} = \exp(-1.6 \lambda_{2211})$$

$$R_{2212} = \exp \left\{-\lambda_{2212} \left[1.6 (.9 \times .75 + .1)\right]\right\} = \exp \left(-1.2 \lambda_{2212}\right)$$

$$R_{2220} = \exp(-1.6 \lambda_{2220})$$

$$R_{2230} = \exp (-1.6 \lambda_{2230})$$

$$R_{2240} = \exp (1.6 \lambda_{2240})$$

$$R_{2250} = \exp(-1.6 \lambda_{2250})$$

$$R_{2300} = \exp(-3.5 \lambda_{2300})$$

$$R_{2400} = \exp(-1.6 \lambda_{2400})$$

Substituting these values in the expression for $\mathbf{R}_{2000},$ collecting terms and simplifying:

$$R_{2000} = \exp \left\{ -\left[1.6 \left(\lambda_{2100} + \lambda_{2211} + \lambda_{2220} + \lambda_{2230} + \lambda_{2240} + \lambda_{2250} + \lambda_{2400} + 1.2 \lambda_{2212} + 3.5 \lambda_{2300} \right] \right\}$$

4.3 Positioning Set Reliability Model

The Positioning Set subsystem includes 27 PS's, only 5 of which include DDU's. Therefore, the subsystem reliability model is expressed:

$$R_{3000} = (R_{3100} \cdot R_{3200} \cdot R_{3400})^{27} \cdot (R_{3300})^{5}$$

R₃₁₀₀ can be expanded according to Figure 10-7.

$$R_{3100} = R_{3110} \cdot R_{3120} \cdot R_{3130}$$
 $R_{3110} = R_{3111} \cdot R_{3112}$

Expressing each factor in the exponential form by substituting appropriate time and duty cycle values from Figures 10-6 and 10-7. in expression (4):

$$R_{3111} = \exp \left(-1.2 \lambda_{3111}\right)$$

$$R_{3112} = \exp \left[-\lambda_{3112} \left[1.2 \left(.9 \times .02 + .1\right)\right]\right] = \exp \left(-.14 \lambda_{3112}\right)$$

$$R_{3120} = \exp \left(-1.2 \lambda_{3120}\right)$$

$$R_{3130} = \exp \left(-1.2 \lambda_{3130}\right)$$

$$R_{3200} = \exp \left(-5.2 \lambda_{3200}\right)$$

$$R_{3300} = \exp \left(-1.2 \lambda_{3300}\right)$$

 R_{3400} = 1 for this model because battery is not yet defined.

Substituting these values in the expression for R_{3000} , collecting terms, and simplifying:

$$\begin{split} \mathbf{R}_{3000} &= \left\{ \exp[-1.2 \ (\lambda_{3111} + \lambda_{3120} + \lambda_{3130}) - .14 \lambda_{3112} \right. \\ &\left. -5.2 \ \lambda_{3200} \right| \right\}^{27} \\ & \cdot \left\{ \exp[-1.2 \ \lambda_{3300}] \right\}^{5} \end{split}$$

5. Relationship Between Elements of Reliability Model and Hardware Subdivisions

The failure rate factors (λ_{xxx}) represent failure rates of the largest subdivisions of major units of the respective equipment for

which the mission time and duty cycle would be consistent, and correspond to the various blocks of the reliability block diagram. In essentially all cases, these blocks can be further subdivided into modules; however, such subdivision is not necessary in most cases because the block failure rate is equal to the sum of the failure rates of the modules. However, in the case of the RTU's, modules making up the transmit circuitry operate at a lower duty cycle than modules making up the receive circuitry. Module or circuitry operating at the different duty cycles are listed below.

Receive Circuitry (Blocks 1111, 2211 and 3111)

Power Converter

RF/IF

Synthesizer (Receive portion)

Carrier IQ/VCO

Code Detector

CACU (70% of total module failure rate)

Clock IQ/Phase Control

RTU Cable Harness

Transmit Circuitry (Blocks 1112, 2212 and 3112)

Power Amplifier/Modulator

Synthesizer (Transmit Portion)

CACU (30% of total module failure rate)

APPENDIX F-2 LRPDS RELIABILITY ALLOCATION

1. Allocation to Subsystems

The effective maximum allowable system failure rate is 26000 failures per million hours (26,000 f/10⁶). This failure rate is allocated to the three subsystems such that the sum of the failure rates of the individual subsystems is equal to the total system failure rate. Other factors considered in the allocation include the relative subsystem complexity and variation in mission time constraints.

Two basic relationships are used in performing the allocations. First, in a series system, the system reliability is the product of the subsystem reliabilities. Assuming an exponential distribution,

$$\exp(-\lambda_s T) = \frac{N}{1 - 1} \exp(-\lambda_i t_i) = \exp\left[-\sum_{i=1}^{N} \lambda_i t_i\right]$$

Where:

 λ_s = the system failure rate

T = the system mission time (the maximum mission time for any subsystem)

 λ_i = the failure rate for sybsystem i

ti = the mission time for subsystem i

N = the number of subsystems

Taking the logarithm of this expression and rearranging gives:

$$\lambda_{s} = \sum_{i=1}^{N} \frac{\lambda_{i} t_{i}}{T}$$
 (1)

^{1.} The failure rate of a series system is the reciprocal of the MTBF.

Thus, the effective maximum allowable failure rate for the LRPDS =

1/38 hours = .026 failures per hour.

Furthermore, in a series system the system failure rate is the sum of the subsystem failure rates such that

$$\lambda_{s} = \sum_{i=1}^{N} \lambda_{i}$$
 (2)

Both expressions (1) and (2) are used in performing the allocation.

The system and subsystem mission times being assumed for this report arc as follows (see paragraph 2.1.2).

LRPDS System: T = 5.9 hours

PCC Subsystem: $t_{1000} = 5.9$ hours

RPS Subsystem: $t_{2000} = 3.5 \text{ hours}$

PS Subsystem: $t_{3000} = 5.2$ hours

Substituting these values, and the system

$$(\lambda_s = .026 \text{ f/hour})$$

failure rate (λ_s = .025 f/hour) in expressions (1) and (2):

$$\frac{5.9\lambda_{1000}}{5.9} + \frac{3.5\lambda_{2000}}{5.9} + \frac{5.2\lambda_{3000}}{5.9} - .026 \text{ f/hour}$$

$$\lambda_{1000} + .59 \lambda_{2000} + .88 \lambda_{3000} = .026$$
 (3)

$$\lambda_{1000} + \lambda_{2000} + \lambda_{3000} = .026$$
 (4)

These two expressions cannot be solved simultaneously because (1) there are 3 unknowns, and (2) direct solution would provide at least one negative λ value. Therefore, λ values are determined that will satisfy expression (3) and that reflect the relative subsystem

complexity. Different environmental "K-factors" are also considered. Final allocations are determined by adjusting the λ values to satisfy expression (4) while maintaining the relative weights that were established using expression (3).

The following observations are made regarding the complexity and other factors relating to the relative failure rates of the three subsystems.

a. Comparison between RPS and PS: The RPS is not more than 10% more complex than individual PS. Therefore, an individual PS failure rate (λ_{3000}) would be approximately $.9\lambda_{2000}$ in the same environment. However, the PS subsystem consists of 27 individual PS's. Thus, the PS subsystem is estimated to be $27 \times .9 = 24.3$ times as complex as the RPS subsystem. Also, even though the two subsystems operate in different environments, the environmental "K-factors" are the same for both subsystems. Based on these observations, the RPS and PS subsystem failure rates are allocated such that:

$$\lambda_{3000} = 24.3\lambda_{2000} \tag{5}$$

b. Comparison between RPS and PCC: Based on the number and types of blocks in the PCC block diagram (Figure 10-2) as compared to the RPS block diagram (Figure 10-4), it is apparent that the PCC is at least 5 times as complex as the RPS. However, the PCC operates

^{2.} See section 10.4 for a discussion of reliability "K-factors"

in a fixed, ground environment while the RPS operates in an airborne environment. The average ratio between fixed ground and airborne "K-factors" in MIL-HDBK-217A is approximately .16:1. Based on these observations, the system failure rates will be allocated such that:

$$\lambda_{1000} = (5 \times .16) \lambda_{2000}$$

$$\lambda_{1000} = .8 \lambda_{2000}$$
(6)

Substituting (5) and (6) in (3):

$$\lambda_{2000} + .59 \lambda_{2000} + 24.3(.88) \lambda_{2000} = .026$$

$$\lambda_{2000} = \frac{.026}{22.9} = .0011 \text{ f/hour}$$
(7)

Substituting (7) in (5) and (6):

$$\lambda_{3000} = 24.3 \text{ (.0011)} = .0267 \text{ f/hour}$$
 (8)

$$\lambda_{1000} = .8 \text{ (.0011)} = .0009 \text{ f/hour}$$
 (9)

These values are adjusted such that expression (4) is satisfied:

$$\lambda_{1000} + \lambda_{2000} + \lambda_{3000} = .0009 + .0011 + .0267 = .0287$$

But, from (4):

$$\lambda_{1000} + \lambda_{2000} + \lambda_{3000} - .026$$

Therefore, the $\frac{.026}{.0287}$ = .91 and adjusted slightly to provide the following allocations.

PCC:
$$\lambda_{1000} = .0008 \text{ f/hour} = 800 \text{ f/}10^6$$

RPS:
$$\lambda_{2000} = .0009 \text{ f/hour} = 900 \text{ f/}10^6$$

PS:
$$\lambda_{3000} = .0243 \text{ f/hour} = 24,300 \text{ f/}10^6$$

Total System $\lambda = 26,000 \text{ f/}10^6$

2. Positioning Set Subsystem Allocation

The PS subsystem failure rate (λ_{3000}) is allocated to the lower subdivision first because the Positioning Unit is a fundamental element of the system, and similar units are used in the RPS and PCC subsystems.

The PS subsystem consists of 27 Positioning Sets, 5 of which include a Data Display Unit (DDU). Thus, the subsystem failure rate is allocated to 27 positioning units (block 3100 of Figure 10-6), 27 Crystal Oscillators (block 3200) and 5 DDU's (block 3300). The battery (block 3400) is ignored in the initial allocation because (a) the specific type of battery to be used is in doubt at this time and (b) batteries are highly reliable devices (typical failure rates are in the order of 1 f/10⁶ or less) and therefore, do not contribute significantly to the system failure rate. In the final allocation, a failure rate of 1 f/10⁶ is allocated to the battery.

The PS subsystem reliability is expressed in the model (paragraph 10.2.3c) as:

$$R_{3300} = (R_{3100} \cdot R_{3200})^{27} (R_{3300})^{5}$$
 (10)

Where:

$$R_{3100} = \exp \left| -(1.2 \lambda_{3100}) \right| \tag{11}$$

$$R_{3200} = \exp \left[-(5.2 \lambda_{3200}) \right]$$
 (12)

$$R_{3300} = \exp \left[-(1.2 \lambda_{3300})\right]$$
 (13)

Also, the reliability block diagram (Figure 10-1) gives T_{3000} = 5.2 hours, and the allocated failure rate for this subsystem is $\lambda_{3000} = .0243 \text{ f/hour.}$

Therefore:

$$R_{3000} = \exp \left[- (.0243 \times 5.2) \right]$$
 (14)

Substituting (11), (12), (13) and (14) in (10):

exp [-(.0243 x 5.2] = exp [-(27 x 1.2)
$$\lambda_{3100}$$
 +

$$(27 \times 5.2) \lambda_{3200} + (5 \times 1.2) \lambda_{3300})$$

Taking the logarithm and rearranging:

19.8
$$\lambda_{3100}$$
 + 27 λ_{3200} + 1.15 λ_{3300} = .0243 (15)

Also, this is a series system and,

$$27 \lambda_{3100} + 27 \lambda_{3200} + 5 \lambda_{3300} = .0243$$
 (16)

The following observations are made concerning relative complexities.

a. Comparison of Crystal Oscillator and Positioning Unit. The crystal oscillator consists of approximately 150 parts compared to approximately 2500 parts in the Positioning Unit. Therefore, it is assumed that:

$$\lambda_{3200} = \frac{150}{2500} \lambda_{3100} = .06 \lambda_{3100} \tag{17}$$

b. Comparison of DDU and Positioning Unit: The DDU contains approximately 140 parts, 20 of which are LED indicators. These devices are roughly equal to 14 diodes and one IC, or the equivalent of 16 parts. Therefore, it is assumed that the DDU is approximately 500/2500 as complex as the Positioning Unit, and:

$$\lambda_{3300} = .2\lambda_{3100}$$
 (18)

Substituting (17) and (18) in (15):

$$19.8\lambda_{3100} + 27 (.06\lambda_{3100}) + 1.15 (.2 \lambda_{3100}) = .0243$$
$$\lambda_{3100} = \frac{.0243}{21.65} = .00113$$

Substituting this value in (17) and (18):

$$\lambda_{3200} = .06 \times .00113 = .00007$$
 $\lambda_{3300} = .2 \times .00113 = .000226$

This is checked in (15) which states:

$$27\lambda_{3100} + 27\lambda_{3200} + 5\lambda_{3300} - .0243$$

But, substituting the calculated λ values:

$$27 \times .00113 + 27 \times .00007 + 5 \times .000225 = .0335$$

Therefore, the $\frac{.0243}{.0335}$ = .73 giving:

Positioning Unit:
$$\lambda_{3100} = .820 \text{ f/}10^6$$

Crystal Oscillator:
$$\lambda_{3200} = 50 \text{ f/10}^6$$

DDU: $\lambda_{3300} = 169 \text{ f/10}^6$

Battery: $\lambda_{3400} = 1 \text{ f/10}^6$

2.1 Positioning Unit Allocation

1

The positioning unit failure rate, $\lambda_{3100} \approx 820 \text{ f/}10^6$ is allocated to the RTU, DPU and control panel in proportion to the estimated failure rates as determined during preliminary predictions. This procedure is used in lieu of a complexity or part count weighting procedure because the analog circuitry of the RTU is expected to have considerable higher failure rate to part count ratio than the digital circuitry of the DPU.

A preliminary prediction that was available before this allocation was performed indicating approximate failure rates as follows:

Unit	Failure Rate	Percentage
RTU	680	.60
DPU	210	. 20
Cont. Panel	220	.20
Total	1110	1.00

^{3.} These are preliminary and are used for weighting quantities only. See section 10.4 for actual prediction results.

Using these percentage as weighting factors provides the following allocation of Positioning unit failure rates:

RTU:
$$\lambda_{3110} = 820 \times .60 = 490 \text{ f/}10^6$$

DPU: $\lambda_{3120} = 820 \times .20 = 165 \text{ f/}10^6$

Cont. Panel: $\lambda_{3130} = 820 \times .20 = 165 \text{ f/}10^6$

2.2.1 Allocation to Modules of PS Positioning Unit:

The RTU and DPU allocations are allocated to modules using approximate failure rates obtained from the preliminary predictions. These allocations are listed in Table F-2.1.

3. Reference Position Set Allocation

The Reference Position Set consists of a Control and Monitor Unit (block 2100 of Figure 10-4), a Reference Position Unit (block 2200), a Rubidium Frequency Standard (block 2300) and an Altimeter (block 2400). The subsystem reliability can be expressed according to the model (paragraph 2.1.5b) as:

$$R_{2000} = R_{2100} \cdot R_{2200} \cdot R_{2300} \cdot R_{2400}$$
 (19)

Where:

$$R_{2100} = \exp(-1.6\lambda_{2100})$$
 (20)

$$R_{2200} = \exp(-1.6\lambda_{2200})$$
 (21)

$$R_{2300} = \exp(-3.5\lambda_{2300})$$
 (22)

$$R_{2400} = \exp(-1.5 \lambda_{2400})$$

Also, the reliability block diagram (Figure 10-1) gives T_{2000} = 3.5 hours, and the allocated failure rate for this subsystem is λ_{2000} = 900 f/10⁶= .0009 f/hour

Therefore:

$$R_{2000} = \exp \left[- (.0009 \times 3.5) \right]$$
 (23)

Substituting (20), (21), (22), and (23) in (19):

$$\exp \left[-(.0009 \times 3.5)\right] = \exp \left[-(1.6\lambda_{2100} + 1.6\lambda_{2200} + 1.6\lambda_{2300})\right]$$

Taking the logarithm and rearranging:

.46
$$(\lambda_{2100} + \lambda_{2200} + \lambda_{2400}) + \lambda_{2300} = .0009$$
 (24)

Also, the RPS is a series system, and

$$\lambda_{2100} + \lambda_{2200} + \lambda_{2300} + \lambda_{2400} = .0009$$
 (25)

The following observations are made regarding the relative complexity of RPS units.

a. The Reference Position Unit is similar to, but somewhat more complex than the PS Positioning Unit. The unit contains more digital circuitry, a more complex memory unit, and a separate memory power supply. However, the unit does not contain the 33 data switches such as are included on the PS control panel. Therefore, the Reference Position Unit should be only slightly less reliable than the PS Positioning Unit. The preliminary allocation for the positioning equipment is:

 $\lambda_{2200} = .00150$ f/hour .

(26)

b. The CMU is a relatively simple control box containing switches and indicators for operating the RPS. The unit contains approximately 7 switches, 11 Bite indicators, and 2 electrical connectors. Failure rate values for this type of component is usually in the order of 1 to $5 f/10^6$, so that the total CMU failure rate should be between 20 and $100 f/10^6$. Therefore, the preliminary value for the CMU failure rate allocation is:

 $\lambda_{2100} = .0005 \text{ f/hour}$ (27)

c. The altimeter is a relatively simple device consisting of a transducer and simple A-D converter. The failure rate of this device should be significantly less than that of the CMU. Therefore, the preliminary value assigned to this unit is:

 $\lambda_{2400} = .000005 \text{ f/hour}$ (28)

Substituting (26), (27) and (28) in (24):

.46 (.00150 + .00005 + .000005) + λ_{2300} = .0009

 $\lambda_{2300} = .0009 - .0007 = .00025 \text{ f/hour}$ (29)

The sum of the values of (26), (27), (28) and (29) is

,00150 + .00005 + .000005 + .0002 = .001755

But, from (25), this sum should be .0009.

Therefore, the preliminary & values are adjusted by a factor of

 $\frac{.0009}{.0018}$ = .50, and the allocated values are:

CMU: $\lambda_{2100} = 23 \text{ f/}10^6$

Ref Pos Unit: $\lambda_{2200} = 750 \text{ f/10}^6$

Rubidum std: $\lambda_{2300} = 125 \text{ f/10}^6$

Altimeter: $\lambda_{2400} = 2 \text{ f/}10^6$

3.1 Reference Position Unit:

The Reference Position Unit (block 2200) consists of five units as shown in Figure 2-5. The RTU is identical to the PS RTU and is allocated the same failure rate, such that:

$$\lambda_{2210} = .00049 \text{ f/hour}$$

The DPU (block 2220) is similar to the PS DPU in construction. The memory, which is included as part of the PS DPU, is a separate unit in the RPS. However, there are approximately twice as many digital modules, each of which is similar in complexity to the PS DPU modules. Therefore, the preliminary allocation for the RPS DPU is approximately the same as for the PS DPU, or:

$$\lambda_{2220} = .00015 \text{ f/hour}$$

The remaining failure rate of .00019 is allocated to the memory (block 2230), memory power supply (block 2240), and the Antenna Filter (block 2250) in relation to the estimated relative complexity. The preliminary allocation for the positioning equipment is:

RTU:
$$\lambda_{2210} = 490 \text{ f/10}^6$$

DPU: $\lambda_{2220} = 150 \text{ f/10}^6$

Memory: $\lambda_{2230} = 75 \text{ f/10}^6$

Memory P.S.: $\lambda_{2240} = 33 \text{ f/10}^6$

Antenna Filter: $\lambda_{2250} = 2 \text{ f/10}^6$

3.1.1 Allocation to Modules of the Reference Position Unit

Failure rates of the RTU are allocated to modules in accordance with the allocations to comparable modules of the PS RTU (block 3110), and are summarized in Table B-1. (Allocations to low subdivisions of the other units will be performed at a later date.)

4. Position Computing Central Allocation

Due to the preliminary status of the PCC subsystem definition, the allocation will be performed for the PCC/PS (block 1100) only. The remaining portion of the subsystem failure rate will be allocated to the other units when the subsystem is sufficiently defined.

The PCC/PS is essentially the same as the PS, (including positioning unit and master oscillator). However, the sheltered ground environment, and the environmental "K-factor" is less by a factor of approximately .16:1. Also, the PS control panel is not used.

Therefore, the allocation to the PCC/PS is .16 times the PS, or:

$$\lambda_{1220} = .16 (\lambda_{3100} + \lambda_{3200}) = .16 (820 + 50 - 165)$$

$$\lambda_{1220} = 115 \text{ f/}10^6$$

This is allocated to the various units and modules of the PCC/PS by multiplying the respective PS module failure rates by .16. The results of this allocation is presented in Table F-2.1.

TABLE F-2. FAILURE RATE ALLOCATION SUMMARY

SYSTEM	BLOCK		E RATE	ALLOCA	E) SHULTI	F/IUCHR.
BREAKDOWN	NUMBER	SYSTEM	SUESIS	MAJUR	UNIT	MUDULE
AN/USO-56 (V)	0000	26,000				
AN/TSQ-100	1000		800			
PCC/PS	1220			115		
RTU					80	
POWER CONV.						8
RF/IF	-				Ì	4
PA/MODULATOR	-		27 T		1	25
FREQ. SYNTH(TE	₹ -				1	22
CARR 19/VCO	-					9
CODE DETECTOR	_					3
CACU						4
CLOCK 1Q/PH. CONT	-					5
DPU	1223				27	
RCDU	· -					4
POWER SUPPLY	_					7
WORD CONTROL	_				Į.	2
MESSAGE OUTPUT	-					.2
DATA ASS SIIBLER	-					2
COMMAND DECODE	R -					2
MEMORY	-			1		3
CABLE HARNESS	-					4
CRYSTAL FREQ. STP.	1224				8	
ALL OTHER PCC UNITS	Ì			685		
AN/ ASO-148	2000		900			1.
CONT - MONITOR UNIT	2100			23		
REFERENCE POSITION UN	1 2200			750		
RTU	2210			1	490	
POWER CONVERT.	-			1		42
RF/IF	-					18
PA/MODULATOR						142
FREQ. SYNTH. (TER) -					127
CARRIQ/VCO	-					52
CODE DETECTOR	-					15
CACU	_					19
CLOCK 1Q/FH. CON	r!					64
CABLE HARNESS	-					11
DPU	2270				150	
MEMORY	2230				75	
MEMORY P.S.	2240				33	
ANTENNA FILTER	22.50				2	
RUBIDIUM FREQ STD	2300			125		
ALTIMETER	2400			2		

TABLE F-2.1 FAILURE RATE ALLOCATION SUMMARY (CONTINUED)

SYSTEM	BLOCK	FAILURE	RATEA	LLOCATI	ON (f/10	(अभ भ
BREAKDOWN	NUMBER	SYSTEM	SUBSYS	MAJOR	UNIT	MODULE
AN/PSQ-101 FULL SUBSYSTEM (27 PS'S AND 5DPU'S) POSITIONING UNIT	3000		24,300	820		
RTU POWER CONV RF/IF PA/MOUULATOR FREA.SYNTH (TER) CARR 10/VCO	3110				490	42 18 142 127 52
CARK 187 VCO CODE DETECTOR CACU CLOCK 19/PH.CONT CABLE HARNESS DPU	3120	·			115	15 19 64
RCDU POWER SUFPLY WORD CONTROL MSG OUTPUT DATA ASSEMBLER CMD DECODER			·			21 44 13 13 13
MEMORY CABLE HARNESS CONTROL PANEL CRYSTAL FRER STD DATA DISPLAY UNIT BATTERY	3130 3200 3300 3400			50 169	165	21 27
				_	7	
	= =			<u>-</u>		
				=		
4 - 1						

APPENDIX F-3 RELIABILITY CALCULATIONS

1. RELIABILITY MODEL SOLUTIONS

"Standard Mission" reliability values are calculated below for allocated failure reates, and for worst case, typical operation, and reliability test prediction failure rates.

1.1 PCC MISSION RELIABILITY

The PCC Reliability for the standard mission is calculated using the allocated failure rates (See Table F-2.1).

The reliability mathematical model for the PCC subsystem is:

$$R_{1000} = \exp \left\{ -[1.6 \ (\lambda_{1221} + \lambda_{1223}) + .2 \ (\lambda_{1222}) + 5.9 \ (\lambda_{1224} + \lambda_{1220} + \lambda_{1500} + 1.9 \ (\lambda_{1300} + \lambda_{1400})) \right\}$$

λ values are determined as follows from allocated failure rates, and considering the hardware items included in each block of the reliability block diagram.

Block	Item	Failure Rate (F/10 ⁶)
1221	RTU Receive Circuitry	
	Power Converter	8 .
	RF/IF	4
	Receive Synth	11
	Carr. IQ/VCO	9
	Code Detector	3
	70% of CACU	3
	Clock IQ/PH. Cont	5
	Total Alli	43
1223	טפט	27

Block	<u>Item</u>	Failure Rate (f/10 ⁶)
1222	RTU Transmit Circuitry	
	PA/Modulator	25
	Trans. Synth	11
	30% of CACU	1
	Total λ_{1112}	37
1224	Crystal Freq. Std.	· · ·8
	All other PCC Units	685

Substituting these values in the model:

$$R_{1000} = \exp \left\{ -[\ 1.6\ (.00007) + .2\ (.000037) + 5.9\ (.000008) + 1.9\ (.000685)] \right\}$$

$$= \exp \left(-.00147 \right) = .9985$$

1.2 RPS MISSION RELIABILITY

The RPS reliability for the standard mission is calculated using allocated failure rates from Table F-2.1, and worst case, typical operation, and reliability test failure rates from the prediction data sheets in Appendix F-4. (See Table F-3.1).

The reliability mathematical model for the RPS subsystem is:

$$R_{2000} = \exp \left\{ -[1.6 (\lambda_{2100} + \lambda_{2212} + \lambda_{2220} + \lambda_{2230} + \lambda_{2240} + \lambda_{2250}) + 1.2 \lambda_{2212} + 3.5 \lambda_{2300}] \right\}$$

Substituting these data in the reliability model gives allocated and predicted mission reliability as follows:

a. Allocated Reliability:

$$R_{2000} = \exp \left\{ -[1.6 (.000025 + .000291 + .000150 + .000110 + .000060 + .000020) + 1.2 (.000219) + 3.5 (.000025)] \right\}$$
 $R_{2000} = \exp (.0014) = .9986$

b. Worst Case Prediction

$$R_{2000} = \exp \left\{ -[1.6 (.000061 + .000545 + .000295 + .000250 + .000092 + .000001) + 1.2 (.000402) + 3.5 (.001321)] \right\}$$
 $R_{2000} = \exp (-.0071) = .9929$

c. Typical Operation Prediction

$$R_{2000} = \exp \left\{-[1.6 (.000024 + .000275 + .000115 + .000098 + .000056 + .0000002) + 1.2 (.000202) + 3.5 (.000486)]\right\}$$
 $R_{2000} = \exp (-.0029) = .9971$

d. Reliability Test Condition Prediction

$$R_{2000} = \left\{ -[1.6 (.000006 + .000124 + .000064 + .000092 + .000014 + .0000001) + 1.2 (.000075) + 3.5 (.000085)] \right\}$$

$$R_{2000} = \exp(-.00087) = .99913$$

TABLE F-3.1

RPS FAILURE RATE VALUES

			λ (f/10 6)		Ĩ
BLOCK	<u>I TEM</u>	ALLOCATION	WORST CASE	TYPICAL	R TEST
2100	Control & Monitor	25	60.75	24.14	5.72
	Unit		11		ĩ
2211	RTU Receive Circuitry				1
	Power Converter	44	79.51	41.37	9.82
	RF/IF	19	36.01	18.19	7.63
	Receive Synth	66	123.09	65.98	23.38
	Carrier IQ/VCO	54	98.61	52.46	25.78
	Code Detector	16	30.55	13.09	13.67
	70% of CACU	14	29.24	10.18	7.28
	Clock IQ/ph cont.	66	125.43	63.50	31.80
	Cable Harness	12	22.26	10.22	4.35
	Total λ_{2211}	291	544.69	274.99	123.71
2220	DPU	150	295,44	114.99	63.98
2230	Memory	110	250,43	98.37	91.58
2240	Memory Power Supply	60	92.11	55.68	14.18
2250	Antenna Filter	20	1.24	. 18	.11
2212	RTU Transmit Circuitr	v			
	PA/Modulator	147	267.90	132.86	48.62
	Transmitter Synth	66	121,58	64,47	23.06
	30% of CACU	6	12.53	4.37	3,12
	Total λ_{2212}	219	402.01	201.70	74.80
2300	Rubidium Freq. Standa	rd 25	1321.15	486.23	85.15

TABLE F-3.2
PS FAILURE RATE VALUES

λ	(f/10 ⁶)
/	(- / /

BLOCK	ITEM	ALLOCATION	WORST CASE	TYPICAL	R TEST
3111	RTU Receive Circuitry				
	Power Converter	42	81.1	41.4	9.8
	RF/IF	18	36.0	18.2	7.6
	Receiver Synth	64	121.6	55.5	23.4
	Carrier IQ/VCO	52	98.6	52.5	25.8
	Code Detector	15	30.6	13.1	13.7
	70% of CACU	13	26.3	10.2	7.2
	Clock IQ/Ph. cont	64	121.5	63.5	31.8
	Cable Harness	11	22.2	10.2	4.4
	Total λ_{3111}	279	537.9	264.6	123.8
3120	DPU	165	339.1	132.3	75.3
3130	Control Panel	165	257.1	108.3	41.1
3112	RTU Transmit Circuitr	37			,
5112	PA/Modulator	142	267.9	132.9	48.6
	Transmitter Synth	63	121.6	64.5	23.1
	30% of CACU	6	11.3	4.4	3.1
	Total λ_{3112}	211	400.8	201.8	74.8
3200	Crystal Oscillator	50	374.9	73.7	26.7
3300	Data Display Unit	170	165.1	96.6	48.4

1.3 PS SUBSYSTEM MISSION RELIABILITY

The PS subsystem reliability is calculated using allocated failure rates from Table F-2.1 and worst case, typical operation, and reliability test failure rate data from Appendix F-4. (See Table F-3.2). The reliability mathematical model for the PS subsystem is:

$$\begin{split} &R_{3000} = (R_{3100} \cdot R_{3200})^{27} (R_{3300})^{5} \\ &R_{3100} = \exp\left\{-[1.2 (\lambda_{3111} + \lambda_{3120} + \lambda_{3130}) + .14(\lambda_{3112})]\right\} \\ &R_{3200} = \exp\left\{-[5.2 (\lambda_{3200})]\right\} \\ &R_{3300} = \exp\left\{-[1.2 (\lambda_{3300})]\right\} \end{split}$$

The values obtained from Table F-2.1 and Appendix F-4 are listed in Table F-3.2. Substituting these data in the reliability model gives allocated and predicted mission reliability as follows:

a. Allocated Reliability:

$$R_{3100} = \exp \left\{ -[\ 1.2\ (.000279 + .000165 + .000165) + .14\ (.000211)] \right\}$$

$$R_{3100} = \exp \left\{ -[\ 0.00076) = .99924$$

$$R_{3200} = \exp \left\{ -[\ 5.2\ (.000050)] \right\} = \exp \left(-.00026 \right) = .99974$$

$$R_{3300} = \exp \left\{ -[\ 1.2\ (.00017)] \right\} = \exp \left(-.000204 \right) = .9998$$

$$R_{3000} = [\ (.9992)\ (.9997)]^{27}\ (.9998)^{5}$$

$$R_{3000} = (.9989)^{27}\ (.9998)^{5} = .9696$$

b. Worst Case Prediction

$$R_{3100} = \exp\left\{-[1.2 (.000538 + .000339 + .000257) + .14 (.000401)]\right\}$$

$$R_{3100} = \exp\left(-.00142\right) - .9986$$

$$R_{3200} = \exp\left\{-[5.2 (.000374)]\right\} - \exp\left(-.00194\right) - .9981$$

$$R_{3300} = \exp\left\{-[1.2 (.000165)]\right\} - \exp\left(-.000198\right) - .9998$$

$$R_{3000} = [(.9986) (.9981)]^{27} (.9998)^{5} - .9126$$

c. Typical Operation Prediction

$$R_{3100} = \exp\left\{-\left[1.2 \left(.000265 + .000132 + .000108\right) + .14 \left(.000202\right)\right]\right\}$$

$$R_{3100} = \exp\left(-.00063\right) = .9994$$

$$R_{3200} = \exp\left\{-\left[5.2 \left(.000074\right)\right]\right\} = \exp\left(-.00039\right) = .9996$$

$$R_{3300} = \exp\left\{-\left[1.2 \left(.000096\right)\right]\right\} = \exp\left(.000115\right) = .9999$$

$$R_{3000} = \left[\left(.9994\right) \left(.9996\right)\right]^{27} \left(.9999\right)^{5} = .9722$$

d. Reliability Test Condition Prediction

$$R_{3100} = \exp \left\{-\left[1.2(.000124 + .000075 + .000041) + .14(.000074)\right]\right\}$$
 $R_{3100} = \exp \left(-.000308\right) - .9997$
 $R_{3200} = \exp \left\{-\left[5.2(.000027)\right]\right\} - \exp \left(-.00016\right) - .9998$
 $R_{3300} = \exp \left\{-\left[1.2(.000048)\right]\right\} - \exp \left(-.000057\right) - .99995$
 $R_{3000} = \left[(.9997)(.9998)\right]^{27}(.99995)^{5} - .9850$

1.4 RELIABILITY UNDER TEST CONDITIONS

The ability of the system to pass the reliability test can be assessed by extrapolating the predicted reliability for a full system to provide an estimate of the MTBF for a reduced system under reliability test conditions. The reliability test will probably be performed on a system consisting of the following:

- 1 Position Computing Control
- 1 Reference Position Set
- 6 Positioning Sets
- 3 DDU's

The predicted reliabilities for test conditions are:

PCC: $R_{1000} = .9985$

RPS: $R_{2000} = .9991$

PS (one): R3100 - .9997

R₃₂₀₀ - .9998

 $R_{3300} - .9997$

The estimated reliability for the reduced system is:

 $R_{s} = (.9985) (.9991) [(.9997) (.9998)]^{6} (.9997)^{3} = .9928$

Assuming a 2-hour mission:

$$.9928 = \exp \left[-2 \lambda \right]$$

$$2\lambda = .0072,$$

$$\lambda = .0036 \text{ f/hour}$$

MTBF
$$-\frac{1}{\lambda}$$
 - 280 hours

APPENDIX F-4

RELIABILITY PREDICTION DATA SHEETS

- 4.1 AN/PSQ-101 WORST CASE
- 4.2 AN/PSQ-101 TYPICAL OPERATION
- 4.3 AN/PSQ-101 RELIABILITY TEST CONDITIONS
- 4.4 AN/ASQ-148 WORST CASE
- 4.5 AN/ASQ-148 TYPICAL OPERATION
- 4.6 AN/ASQ-148 RELIABILITY TEST CONDITIONS

APPENDIX F-4.1

WORST CASE

RELIABILITY PREDICTION DATA SHEETS

POSITIONING SET AN/PSQ-101

ENVIRONMENT: VEHICLE MOUNTED GROUND

TEMPERATURE: +71°C

STRESS LEVELS: DERATING LIMITS

PROJECT 3995-113 MODULE POWER CONVERTER MODE

YADEL AZT UNIT

71. C

TEMP

DATE AP 12,171

NI SSECTO

COMPONENT DESCRIPTION	710	PERCENT	FACTOR	BASIC FAILJRE RATE	MILLIBY HRS.	F.R. SBURCE	NOTES
CAPACITSH, CEM, CK	3.0		2.00	• 00962	•14423	217A -	
CAPACITORS SLU TANT, CSR	7.0		1.00	•70100	.49073	217A-	
CAPACITBES FBIL TANTS CL	3.0	50	8.00	•16750	4 • 02000	217A-	
C91L, AF	8.0		8.60	• 22000	15 13600	217A-	
CBN	8.0		3.50	• 41000	11 • 48000	217A-	
DIBDE, SILICBN, 1-50 MATI	1.0		12.00	• 90000	10.80000	217A-	
FILTER, FEED THRU	0.6		1.00	•30000	2.70000	217A-	
CARSS	8.0		10.00	•02650	•21200	217A-	
RESISTER'S FIXED METAL FILM	0.4		• 30	• 24850	• 29820	217A-	
	1.0	2 0	10.00	•22000	2.20000	217A-	
TAAKSISTUR, SILICEN APA, 0-1 MATT	1.0	50	8.00	• +1000	3.28000	217A-	
S TRANSISTURIN SILICON APA, 1-50 WATT	1.0	50	8.00	•82000	6.56000	217A -	
	2.0	50	8.00	1.25000	20.00000	217A-	
ZENER DIBDE, 0-1 MATT	1.0	20	3.00	1.25000	3.75000	217A-	
ZENER DIBDE, 0-1 MATT	1.0	20	3.00	1.25000	3.75000		217A-

81.07108 FAILURES PER MILLION HOURS 12334,8555 HBURS YEAN TIME BETWEEN FAILURES EQUALS 19TAL FAILURE RATE EQUALS

DESIGN FAILURE RATE GOAL 45.000

45.00000 FAILURES PER MILLION HOURS

٠,

MBDEL X/T UNIT	
	71. C
	TEMP
2F/1F	
MBDULE	
3995-113	12,171
PRBJECT 3	DATE APR 12,171

		STRESS IN	¥	BASIC	FAILURES PER	F . R.	
COMPONENT DESCRIPTION	QTY	PERCENT	FACTOR	FAILURE RATE	MILLIBN HRS.	SOURCE	NUTES
CAPACITOR, CER, CK	15.0		5.00	•00962	•72113	217A	
CAPACITOR, MICA, CM	2.0		15.00	•00036	•01072	217A	
COIL, RF	1.0	50	8 • 60	• 22000	1 • 89200	217A	
CONNECTOR, RF	3.5		4.00	000000	• 56000	217A	
CONNECTOR, 15 PINS	S.		00.9	.34300	1.02900	217A	
INTEGRATED CIRCUIT, LINEAR	5.0		1.00	00004.	2.00000	217A	
RELAY, HALF CRYSTAL CAN	1.0	50	50.00	•00310	•15500	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION	19	50	10.00	•02650	• 50353	217A	
S. RESISTOR, NON-WE VAR. L. S. ACT.	1.0	50	8.30	49.12999	9.82600	217A	1
DIGDE, HOT CARRIER	0.4		3.50	1.03000	14.42000	217A	
TRANSFORMER, KF	2.0		10.00	• 22000	4 • 40000	217A	
	2.0		1.00	•24700	00464.	217A	

S

36.C1131 FAILURES PER MILLION HOURS 20.00000 FAILURES PER MILLION HBURS MEAN TIME BETWEEN FAILURES EQUALS 27769.0547 HBURS TOTAL FAILURE RATE EQUALS DESIGN FAILURE RATE GOAL

NOTE1: FACTOR OF 0.1 APPLIED TO FAILURE RATE DUE TO NO FIELD ADJUSTMENTS

POWER AMPLIFIER MEDULE PRBJECT 3995-113

APR 12, 171 DATE

MADEL AZT UNIT

U 71.

TEMP

SALES F.R. SBURCE 217A 217A 217A FAILURES PER MILLIBN HRS. •96000 2.04003 7.14000 .39353 22.00000 45 - 40800 3+350+2 SASIC FAILURE RATE 000000 .25500 .01193 •25500 •51000 •65000 .01098 •22030 •22000 .67030 FACT9R 5.00 8 000 STRESS IN OITY PERCENT 0000000000 4 w w w w o w + w RESISTOR, FIXED CARBON COMPOSITION TRANSISTUR, FIELD EFFECT
TRANSISTUR, SILICON NPV. 0-1 AATT
TRANSISTUR, SILICON NPV. 1-50 WATT COMPONENT DESCRIPTION DIBDE, HOT CARRIER DIBDE, SILICON, 0-1 MATT CAPACITOR, CER, CK TRANSFORMER, RF COIL, RF CONVECTOR, RF

173.07690 FAILURES PER MILLIBN HBURS TOTAL FAILURE RATE EQUALS

F-39

5777.7773 HBURS MEAN TIME BETWEEN FAILURES EQUALS

DESIGN PAILURE RATE GOAL

97.00000 FAILURES PER MILLION HOURS

MODEL AZT UNIT	U
	71. C
XMTR MBDULATBR	TEMP
MBDULE	
T 3995-113	APR 12, 171
PRBJECT	DATE

COMPONENT DESCRIPTION	<u>≻</u> ±	STRESS IN PERCENT	FACTOR	BASIC FAILJRE RATE	FAILURES PER MILLIBN HRS.	F.R. SBURCE	NUTES
CAPACITON, CEN, CK	0.9		5.00	• 00962	.28845	217A -	
CAPACITOR, SLD TANT, "CSR	2.0	50	1.00	.70100	•14020	217A -	
COIL, RF	2.0		8 • 60	• 22000	3.78400	217A-	
DIODE, HOT CARRIER	8.0		3.50	1.03000	28 • 83998	217A-	
DIBDE, SILICON, 0-1 AATT	10.0		3.50	• +1000	14.35000	217A-	
INTEGRATED CIRCUIT, LINEAR	9.0		1.00	00004•	•80000	217A-	
RELAY, HALF CRYSTAL CAN	3.0		50.00	•00310	• 46500	217A -	
S. RESISTOR, FIXED CARBON COMPOSITION	30.0		10.00	•05650	• 795 00	217A-	
TRACSTORMEN, KF	0.4		10.00	• 22000	8.80000	217A -	
	10.0		8 • 00	• +1000	32.79999	217A -	
L ZENER DIBDE, 0-1 WATT	1.0		3.00	1.25000	3.75000	217A -	
0							

94.81258 FAILURES PER MILLION HOURS 53.00000 FAILURES PER MILLIUN HOURS 10547.1211 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FAILURE RATE EQUALS DESIGN FAILURE RATE GOAL

YSTORBLA, INC. FAILURE RATE DETERMINATION

MBDEL AZT UNIT	
	71. 6
FREG SYN 1	TEMB
MODULE	
PRBJECT 3995-113	DATE APR 12.171
PRBJE	DATE

COMPONENT DESCRIPTION	Y	GTY PERCENT FACTOR	FACTOR	FAILURE RATE	FAILURES PER	S. B. I. S. P.	0 4 th
CAPACITOR, CER, CK	22.0		5.00	•00962	1.05765	2174	
CAPACITOR, MICA, CM	16.0		1000	46000		1	
			00.01		00000	V/13	
COIL, AF	8.0		8 • 60	• 22000	15-13600	217A-	
DIBDE, HBT CARRIER	12.0		3.50	1.03000	43.25998	217A-	
DIODE, SILICON, 0-1 AATT	0.0	50	3.50	00014	7.175.00	217A-	
INTEGRATED CINCUIT, LIVEAR	2.0		1.00	00004	00008	2174	
SA RESISTOR, FIXED CARBON COMPOSITION	57.0		10.00	0.0000	1.51050	177.0	
TRANSISTER. SILICEN AP	4.0				000000	2777	
			000	0001	66610461	C1/A-	
	ů ů		8 • CO	1.25000	20.00000	217A-	
TANSFORMER, KF	0.4		10.00	• 22000	8 • 80000	217A-	
P RESISTOR, VARIABLE, 10-TURN	1.0		2.00	2.03900	4.07800	SM-188-	

TOTAL FAILURE RATE EQUALS 121.	5828
DESIGN FAILURE RATE GOAL	AR-DOOD FAILURES PER MILITAN HAURS

49DEL AZT UNIT	
	71. C
FREG SYN 2 (REC)	LEMP
MEDULE	
PM9JELT 3995-113	DATE APH 21,171

COMPUNENT DESCRIPTION	¥13	STRESS IN PERCENT	FACTOR	HASIC FAILURE KATE	FAILURES PER MILLION HRS.	F.R. SBURGE	S
CAPACITUM, CEM, CA	0.67		00.00	67600	1.05745	24.74	
	1				00000	2/13	
CAPACITURE MICAS CM	10.0		15.00	•00036	· 08580	217A	
COLL RF	8.0		6.60	•22000	15.13600	217A	
DIBDE, HUT CARRIER	12.0		3.50	10.126.1	ADERO E4	A7 1 C	
110 210 CO				0000	でしている。	W/13	
DIGDER STRICTS OF ANI	2.0		3.50	. 41000	7-17500	21/A	
INTEGRATED CIRCUITA LINEAR	2.0		1.00	• 40000	• 30000	217A	
THESISTERS FIXED CAADON COMPOSITION	57.0		10.00	.02650	1.51050	217A	
TRANSISTERS SILICEN APAN 0-1 AATT	0.0		8.00	• 41650	65629-61	21.7A	
TRANSISTUR, SILICON PNP, 0-1 NATT	2.0		8 - 00	1.25000	20.00000	217A	
A TRANSFURNITIES AF	4.0		10.00	•22000	8 - 80000	21.7A	
FESISTERN VARIABLENIC-TURN	1.0	5. C	8.00	2.03900	4.0780.3	SM-188	
15.00とどのはなる。 お子	3.0		4.00	000+0•	0.084.	217A	
CONVECTOR 15 PINS	.5	5 0	6.60	.34300	1.02900	217A	

123.09186 FAILURES PER MILLION HOURS 8124.0117 H6JRS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FAILUNE NATE EGUALS

MODEL AZT UNIT	
	71. 5
16/408	TEMP
CARRIER IG/VCB	
HBDULE	
3995-113	DATE APR 12,171
PRBJECT	DATE AP

TES

			STRESS IN		BASIC	AILURES P	4	
	COMPONENT DESCRIPTION	QTY	PERCENT	FACTBR	FAILURE RATE	IRS		101
	CAPACITOR, VAR AIR, CT	•	5	•	470	0.464.	-	
	· CER		09	•	960	9	• •	
	CAPACITOR, MICA, CM	14.0	90	15.00	•00036	• 075	217A	
	COIL, RF	•	55.	00	S	11+35200	, 🛶	
	CONNECTOR, RF	•	5 ₀	•	000000	.)	-	
	CONNECTOR, 8 PINS	S.	50	•	82	460	•	
	CON, 0-1	0.0	50	•	10	750	-	
	CIRCUIT	•	ည	•	00000	• 200g	•	
	D CIRC	•	<u>ي</u> م	•	· 40000	.609	•	
\$	RESISTOR,	ò	20	10.00	•02650	200	•	
-		•	2 0	•	•24850	.0128	_	
4	RESISTOR, WH VAR. LEAD SCREW ACT.	3.0	50	18.00	.17075	9.22050	•	
4	TRANSISTOR, SILICON NPV. 0-1 MATT	•	20	8	• 41000	6666.9	_	
3	DIODE	•	20	3.00	1.25000	500	•	
	DIODE, HOT CARRIER	•	20	•	1.03000	* . *	•	
	TRANSFORMER, RF	•	50	10.00	• 22000	O	-	
	CRYSTAL, QUARTZ	3.0	50	1.00	• 02000	00090	•	
		0.4	20	•	9	.240	-	
	CAPACITOR, VAR GLASS, PC	•	50	•	4	500		
		1.0	50	1.00	4	*	•	
Š	PESISTOR, FIXED METAL FILM	2.0	2 0	• 30	.24850	• 100•	-	

98.60519 FAILURES PER MILLIBN HBURS 55.00000 FAILURES PER MILLIUN HOURS 10141.4531 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FALLURE RATE EQUALS DESIGN FAILURE RATE GOAL

MBDEL A/T UNIT	71. C
MODULE CODE DETECTOR	TEMP
PRBJECT 3995-113	DATE APR 12, 171

COMPONENT DESCRIPTION	S	STRESS IN K GTY PERCENT FACTOR	FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION ARS.	F.R. SBURCE	NOTES
CAPACITOR, CER, CK	46.0	9	5.00	• 00962	2.21145	217A-	
CAPACITOR, MICA, CM	0.4	9	15.00	•00036	•02145	217A-	
CONNECTOR, 15 PINS	ហ	50	00.9	•34300	1.02900	2174-	
DIODE, SILICON, 0-1 WATT	7.0	50	3.50	•41000	10.04500	217A_	
INTEGRATED CIRCUIT, DIGITAL	3.0	50	1.00	00004.	1.20000	217A-	
INTEGRATED CIRCUIT, LINEAR	19.0	20	1.00	00004•	7 • 60000	217A-	
RESISTOR, FIXED METAL FILM	28.0	50	• 30	• 24850	2.087.0	217A-	
FESISTOR, WW VAR. LEAD SCREW ACT.	1.0	50	18.00	•17075	3.07353	RADC	
TRANSISTOR, SILICON VPV. 0-1 WATT	1.0	20	8 - 22	•41000	3.28000	217A-	

30.54776 FAILURES PER MILLION HOURS	32735.6211 HBURS	17.00000 FAILURES PER MILLIUN HOURS
TOTAL FAILURE RATE EQUALS	MEAN TIME BETWEEN FAILURES EQUALS	DESIGN FAILURE RATE GOAL

MODEL K/T UNIT	
	71. C
	71
CACU (DISITAL)	TEMP
HEDALE	
CT 3995-113	DATE APR 12,171
PHBJECT	DATE

	0.	STRESS IN	¥	BASIC	FAILURES PER	A.	
COMPONENT DESCRIPTION	QTY	GTY PERCENT FACTOR	FACTOR	FAILURE RATE	MILLIBY 425.	SBURCE	NOTES
CAPACITOR, CER, CK	30.0	6.0	5.00	•00962	1.44225	217A -	
INTEGRATED CIRCUIT, DISITAL	71.0	50	1.00	.40000	28 • 39999	217A-	
RELAY, HALF CHYSTAL CAN	1.0	50	50.00	.00310	• 15500	217A -	
* RESISTOR, FIXED CARBON COMPOSITION	54.0	50	10.00	• 02650	1-43100	217A-	
CAPACITOR, MICA, CM	9.0	9	15.00	•00036	• 03218	217A -	
COIL, RF	3.0	2 0	8.60	• 22000	5.67600	217A-	
CONNECTOR, RF	3.0	50	4.00	000000	• 48000	217A-	

37.61639 FAILURES PER MILLION HOURS TOTAL FAILURE RATE EGUALS

MEAN TIME BETWEEN FAILURES EQUALS 26584.1523 HBURS

21.00000 FAILURES PER MILLISM HOURS DESIGN FAILURE RATE GOAL

40DEL A/T UNIT	
TECT98	P 71. C
CLOCK IG DETECTS	TEMP
MBDULE	
PR6JECT 3995-113	DATE APR 12,171

		STRESS IN	¥ (BASIC	FAILURES PER	F. R.	
CONFORM DESCRIPTION	4	PERCENT	FACTSK	FAILURE MATE	ILLION HE	SBURCE	NOTES
CAPACITOR, VAR AIR, CT	1.0	S C	1.00		3		
CAPACITOR, CER, CK	36.0	9	•	• 00962	0	~	
CAPACITOR, MICA, CM	•	90	15.00		S	174	
COIL, RF	•	20	•	• 22000	11.35200	17	
CONNECTOR, RF	2.5	50	6.00	•04000	0,0004.	-	
CONNECTOR, 8 PINS	•	20	00.9	•18200	•54600		
DIBDE, SILICON, 0-1 MATT	5.0	20	•	• +1000	2.87000	17	
INTEGRATED CIRCUIT, LINEAR	•	50	1.00	00004.	•	17	
RESISTOR, FIXED CARBON COMPOSITION		20	10.00	• 02650	1.27200		
FIXED METAL FILM	13.0	50	• 30	• 24850	•96915	17	
RESISTOR, WW VAR. LEAD SCREW ACT.	1.0	90	18.00	•17075	3 07350	-	
TRANSFORMER, RF	0.9	20	10.00	• 22000	•	-	
TRANSISTOR, SILICON NPV. 0-1 MATT		20	•	100	•	17	
ZENER DIBDE, 0-1 WATT	1.0	50	•	S	3.75000	N	•
DIODE, HOT CARRIER	0.4	50	3.50	1.03000	14.42000		
CAPACITOR, T C CER, CC	4.0	50	2.00	•06200	1.24000		
CRYSTAL, QUARTZ	2.0	SC S	1.00	• 05000	000000	217A-	
CKISIALS GUARIZ	•	20	1.00	• 05000	•		174

HOURS		BURS
66.52388 FAILURES PER MILLION HOURS		37.00000 FAILURES PER MILITAN HBURS
PER	HOURS	PER
AILURES	15032-1953 HOURS	THURES
52388 F		0000
•99	EGUALS	37.6
TOTAL FAILURE RATE EQUALS	MEAN TIME BETWEEN FAILURES EQUALS	GBAL
RATE	EEN F	DESIGN FAILURE RATE GRAL
LURE	BETH	ILURE
FAI	T1%	AN NE
TOTA	MEAN	DESI

MATE DETERMINATION

MADEL AZT UNIT 71. C MEDULE CLECK PHASE CONTROL TEMP PR0JECT 3995-113 DATE APR 12, 71

	COMPONENT DESCRIPTION	710	PERCENT	FACTBR	BASIC FAILURE RAIE	FAILURES PER MILLION HRS.	SOURCE	NOTES
		:					;	
	CAPACITORS CERS CR	7000		2.00	• 00267	1.82680	217A -	
	CAPACITOR, MICA, CM	*		15.00	•00036	• 02145	217A-	
	COIL, RF	0.0		8 • 60	• 22000	00094.6	217A -	
	DIBDE, SILICON, 0-1 MATT	1.0		3.50	• 41000	1 • 43500	- AL 12	
	INTEGRATED CINCUIT, DIGITAL	0.4		1.00	00004	1.60003	217A-	
	INTEGRATED CIRCUIT, LIVEAR	12.0		1.00	• 40000	4.80000	217A -	
Š		28.0		10.00	• 02650	•74200	2174-	
	RESISTOR, FIXED METAL FILM	10.0		900	• 24850	•74550	217A-	
F-	RESISTOR, WW VAR. LEAD SCREW ACT.	1.0	50	18.00	•17075	3.07350	RADC	
• 4	TRANSFORMER, RF	2.0	20	10.00	• 22000	11.00000	217A-	
7	TRANSISTOR, SILICON NPV, 0+1 HATT	1.0		8.00	• 41000	3.28000	217A -	
	DIBDE, HOT CARRIER	*		3.50	1.03000	14.42000	217A-	
	CAPACITOR, T C CER, CC	8.0		5.00	•06200	2.48000	217A-	
	CRYSTAL, QUARTZ	4.0		1.00	•05000	000800	2174-	

54.96423 FAILURES PER MILLION MOURS 30.00000 FAILURES PER MILLION HOURS 18193.6484 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FAILURE RATE EQUALS DESIGN FAILURE RATE GOAL

MATERIAN INC. FAILURE MATE DETERMINATION PROJECT 3995-113 MROULE RTU CADLE HARNESS
DATE APA 21,'71
TEMP 71. C

MODEL POSITIONING SET

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7:00
U

CONVECTOR RF CONVECTOR 8 PINS CONVECTOR 15 PINS CONVECTOR 36 PINS

F.R. SBURCE	217A	217A	217A	217A
FAILURES PER MILLIBN ARS.	2.88000	2.18403	6 • 17 4 6 0	11.02500
BASIC FAILURE RAIE	.04000	•13200	• 34300	1.22500
K FACTBR	4 • 0:0	6.00	0.00	6•50
STRESS IN K UTY PERCENT FACTOR	50	50	50	50
ν 7	14.0	၁• ဂ	0.0	1.5

NUTES

TETAL FALLURE RATE EQUALS

MEAN 114E BETWEEN FAILURES EQUALS

22.26300 FAILURES PER MILLION HOURS

44917.5742 HBURS

MOTORDA INC. FAILURE RATE DETERMINATION

MADEL POSITIONING SET	71• C
	71
RC3U-DPU	TEMP
MODULE	
PR6JECT 3995-113	DATE APR 12,171

	COMPONENT DESCRIPTION	TE	PERCENT	FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION ARS.	SOURCE	NUTES
	CAPACITOR, CER, CK	68.0	9	5.00	67630.	2.2695	2174	
	CAPACITOR, T.C. CFR. CC		יו ה			00000		
)		00000	00030	C1/A1	
		20.0	09	15.00	•00036	.10725	217A -	
	CAPACITOR, SLD TANT, CSR	5.0	50	1.00	•70100	• 35050	217A-	
	COIL, AUDIO	1.0	50	16.00	.22750	2.27500	217A -	
	COIL, RF	3.0	50	8•60	• 22000	5.67600	217A -	
	INTEGRATED CIRCUIT, DISITAL	41.0	50	1.00	00004	16.39999	2174	
	INTEGRATED CIRCUIT, LIVEAR	12.0	50	1.00	000040	4.80000	217A.	
2	RESISTOR,	54.0	50	10.00	•02650	1.43100	217A -	
	RESISTOR, FIXED METAL FILM	8.0	50	• 30	•24850	• 59640	217A -	
F-	TRANSFORMER, KF	2.0	2 0	10.00	• 22000	00004 • 4	217A -	
49	TRANSISTOR, SILICON APL, 0-1 AATT	1.0	20	8.00	•41000	3.28000	217A -	

43.20520 FAILURES PER MILLION HOURS 21.00000 FAILURES PER MILLION HOURS 23145.3594 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FAILURE RATE EQUALS DESIGN FAILURE RATE GOAL

MOTORGIA, INC. FAILURE RATE DETERMINATION

MODEL POSITIONING	
	71. C
DPU PWR SUP	TEMP
BUDGE	
PRBJECT 3995-113	DATE APR 12,171

SET

	COMPONENT DESCRIPTION	7	STRESS IN	FACTOR	BASIC FAILURE RATE	FAILURES PER MILLIBY ARS.	F.R. SBURCE	NOTES
)	1
	CAPACITOR, SLO TANT, CSR	0.9	50	1.00	•76100	• 42060	217A_	
	CAPACITOR, FOIL TANT, CL	2.0	50	8.00	1675	• 6	17A	
_	COIL, AUDIB	1.0	50	10.00	•22750	2.27500	1	
	DIBDE, SILICON, 0-1 WATT	15.0	5C	3.50	• 41000	21.52499	17	
	RELAY, HALF CRYSTAL CAN	1.0	20	50.00	•00310	.15500	17	
5.	RESISTOR, FIXED CARBON COMPOSITION	19.0	20	10.00	• 02650	• 50350	17	
_	RESISTOR, FIXED METAL FILM	2.0	20	•30	•24850	• 001 + 9	17A	
	TRANSFORMER, POWER	1.0	20	10.00	• 22000	2.20000	217A-	
	アロア	0.4	5 S	8 . 00	• 41000	13.12000	17	
5	SILICON APA		50	8 • 00	•82000	6.56000	217A -	
•	TRANSISTOR, SILICON PNP, 0-1 MATT	3.0	2 0	8.00	1.25000	30.00000	217A-	
. •	ZENER DIBDE, 0+1 WATT	•	50	3.00	ທ	11.25000	174	
		3.0	9	5.00	960	.14423	217A-	
	CONNECTOR, 15 PINS		30	00.9	•34300	1.02900	217A-	

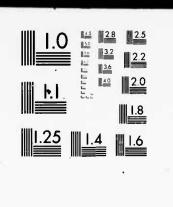
91.86375 FAILURES PER MILLION HOURS 46.00000 FAILURES PER MILLION HOURS 10885.6836 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FAILURE RATE EQUALS DESIGN FAILURE RATE GOAL

		NOTES	
		F.R. SBURCE	217A 217A 217A
MODEL MOSITIONING SET		FAILURES PER MILLIBY HRS.	.72113 7.35000 17.59999 .13250
YBDEL MBS	U	BASIC FAILURE RAFE	. 00962 1.22500 . 40000
NTROL	P 71. C	K FACT9R	10000 10000 10000
DPU WORD CONTROL	TEMP	STRESS IN K	0000
		≻Tū	10 00 00 00 00 00
MBDOLE			1 BN
PRBJECT 3995-113	DATE APR 12,171	COMPONENT DESCRIPTION	CAPACITOR, CER, CK CONVECTOR, 36 PINS INTEGRATED CIRCUIT, DIGITAL SA RESISTOR, FIXED CARBON COMPOSITION

2		S
5		HOUR
25.80360 FAILURES PER MILLISN HBURS		13.00000 FAILURES PER MILLIAN HBURS
71	ທ	41.1
2 2	HBUR	PER
OXES	734	RES
FAIL	54.2	AILU
360	387	00 F
o x		000
လိ	MEAN TIME BETWEEN FAILURES EQUALS 38754.2734 HOURS	13.
ה ה	RES	ب
₹	AILU	69
IBIAL FAILURE MATE EGUALS	L Z	DESIGN FAILURE RATE GBAL
¥ Y	MEE	E A
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MOTOROLA INC SCOTTSDALE ARIZ GOVERNMENT ELECTRONICS DIV AD-AU47 145 F/G 17/3 LRPDS INTERIM TECHNICAL REPORT. APPENDICES, (U)
JUN 71 S ATTWOOD DAAK02-71-C-0022 UNCLASSIFIED NL 3 OF 4 ADAO47145

3 OF 4 ADA047145



MICROCOPY RESOLUTION TEST CHART
NATIONAL BURLAU OF STANDARDS 1963 A

FAILURE RATE DETERMINATION MOTOROLA, INC.

71. C DPU MSG BUTPUT CTRL TEMP MBDULE PRBJECT 3995-113 APR 12,171 DATE

MODEL POSITIONING SET

-,

COMPONENT DESCRIPTION

FAILURES PER MILLION HRS. .76923 7.35000 18.79999 BASIC FAILURE RAFE •00962 STRESS IN K PERCENT FACTOR 5.000

NUTES

SBURCE F.R.

217A - 21

•47700

1.22500 .40000 .02650

3000 16.0 17.0 18.0

INTEGRATED CIRCUIT, DIGITAL RESISTOR, FIXED CARBON CUMPOSITION

CAPACITOR, CER, CK

27.39618 FAILURES PER MILLIBN HBURS TOTAL FAILURE RATE EQUALS

36501.4375 HBURS MEAN TIME BETWEEN FAILURES EQUALS 13.00000 FAILURES PER MILLION HOURS

DESIGN FAILURE RATE GBAL

F-52

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MBTBRBLA, I.C. FAILURE RATE DETERMINATION MODEL POSITIONING SET 71. C MODULE DRU DATA ASMBLR & ST TEMP PRBJECT 3995-113 DATE APR 12, 71

COMPONENT DESCRIPTION	OTY	OTY PERCENT	FACTOR	BASIC FAILURE RATE	MILLION ARS.	SOURCE	MOTES
CAPACITIES LESS LA	12.0		2.00	*00APK	•/6113	C1/A	
CONNECTOR, 36 PINS	1.0		6.30	1.22500	7.35000	217A-	
INTEGRATED CIRCUIT, DIGITAL	46.0	50	1.00	00004.	18.39999	217A -	
S& RESISTOR, FIXED CARBON COMPOSITION	0.9		10.00	•05920	.15900	217A -	

26.63011 FAILURES PER MILLION HOURS	Sx	Sough Wat Little and Shall state Cooperate
֝֟֝֝֟֝֝֟֝֝֝֝ ֡֡֡֡	H	Dro
3011 FAILURES	37551.4727 HBURS	SOON EATTER
56.6	EGUALS	43000
TOTAL FAILURE RATE EQUALS	MEAN TIME BETWEEN FAILURES EQUALS	DESTAN FATINGE DATE GRAI
RATE	EN	DAT
JRE	3ETW	PE
1	AE E	54.
ו	-	Ne
191	MEA	OFC

MODEL POSITIONING SET	
	U
DECODER	71.
DPU COMMAND	TEMP
MADULE	
ECT 3995-113	DATE APR 12,171
PRBJECT	DATE

			STRESS IN	¥	BASIC	FAILURES PER	F. X.	
	COMPONENT DESCRIPTION	GTY	GTY PERCENT	FACTOR	FAILURE RATE	MILLIBY HRS.	SOURCE	NOTES
	X2 - 850 - 668 - 67	4	4	5.00	67600	4727.E	745.6	
	ראבירו ומער בניי	> + 7			30000	00000	21/12	
	CONNECTOR, 36 PINS	1.0	2 0	00.9	1.22500	7.35000	217A-	
	INTEGRATED CIRCUIT, DIGITAL	44.0	50	1.00	00000	17.59999	217A/	
*5	-	20.0	90	10.00	•02650	•53000	217A -	
	CAPACITOR, SLD TANT, CSR	1.0	2 0	1.00	. 70100	.07013	217A-	

HOURS		HOURS
MILLION	(A	MILLIUN
PER	HOUR	PER
26.22313 FAILURES PER MILLION HOURS	38134.2734 HBURS	13.00000 FAILURES PER MILLIUN HOURS
26•22313		13.00000
TOTAL FAILURE RATE EQUALS	MEAN TIME BETWEEN FAILURES EQUALS	ATE GOAL
FAILURE RA	IME BETWEE	DESIGN FAILURE RATE GOAL
TOTAL	MEAN T	DESIGN

MBTBRBLA, INC. FAILURE RATE DETERMINATIBN

ADDEL POSITIONING SET	
5	71. 5
JPU MEMBRY	TEMD
HEDULE	
T 3995-113	APR 12,171
PRBJECT	DATE

UNIE APR 163'71		4 E E		73 • 5			
COMPONENT DESCRIPTION	017	STRESS IN PERCENT	FACT98	BASIC FAILURE RATE	FAILURES PER MILLION MRS.	F.R. SBURCE	NUTES
PACITOR, GLASS, CY	5.0		18.00	.12540	10.83600	217A .	
PACITOR, CER, CK	34.0		5.00	• 00962	1 • 63455	217A-	
PACITOR, SLU TANT, CSR	7.0	200	1.00	.70100	04064	217A-	
INNECTOR, 36 PINS			6.00	1.22500	3.67500	217A-	
ITEGRATED CINCUIT, DISITAL	59.0		1.00	00004.	23.59999	217A-	
SISTOR, FIXED CARBON COMPOSITION	18.0		10.00	•02650	•47700	217A-	
SISTOR, FIXED METAL FILM	*		• 30	•24850	• 00298	217A-	
ITEGRATED CIRCUIT, LINEAR	8		1.00	00004.	3.20000	217A -	

43.91620 FAILURES PER MILLION HOURS 22.00000 FAILURES PER MILLION HOURS 22770.6406 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FAILURE RATE EQUALS DESIGN FAILURE RATE GBAL

YOTOROLA, INC. FAILURE RATE DETERMINATION

i.

	MODEL POSITIONING SET	
,		71. €
•	- 3PJ	
	HARNESS	TEMP
יאורטיב איור סבובאיוזיאיוזי	HODULE CABLE MARNESS-JPJ	
	Medule	
	PRBJECT 3995-113	DATE APR 12,171
	CT 35	APA
	PRBJE	DATE

COMPONENT DESCRIPTION	YTO	OTY PERCENT	IN K	BASIC FAILURE RATE	FAILURES PER MILLION MAS.	F.R. SBURCE	NOTES
CONNECTOR, RF		Š	60.4	00000	00080•	2174	
CONNECTOR, 15 PINS	r.	50	9.00	.34300	1.02903	2174	
CONNECTOR, 36 PINS	7.0	50	9.00	1.22500	51.45001	217A /	
CONNECTOR, 20 PINS	• S	2 0	00.9	• 48630	1.45860	217A	

TOTAL FALLURE RATE EQUALS	54.C1700 FAILURES PER MILLIBN HBURS
MEAN TIME BETWEEN FAILURES EQUALS 18512.6875 HOURS	EQUALS 18512.6875 HBURS
DESIGN FAILURE RATE GOAL	27.00000 FAILURES PER MILLIUN HOURS

Chapter !

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TBRBLA, INC.	TE DETERMINATION
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MOT	RATE
2	AILURE
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BNING SET

A COLUMN

COIL, RF FUSE SWITCH, TOGGLE OR PUSHBUTTON 46.0 50 18.00 .25000 CAPACITOR, CER, CK TANNETION 36 PINS	က က က က ၁၁၁		• 22030			
6.0 50 8.60 1.0 50 1.00 12.0 60 5.00 1.00 5.00	0000	000	• 22000			
1.0 50 18:00 12:0 60 5:00 1:00 50 5:00	ည် သ	000	0.00	11.35200	2174	
12.0 60 5.0 1.0 50 5.0 1.0 50 6.0	20	• 00	00001	.10000	217A	
12.0 60 5.00 1.0 50 6.00			•25000	207-00000	2174	
1.0 50 6.00	3	000	•00962	•57690	2174	
	50	000	1.22500	7.35000	217A	
DIGITAL 66.0 50 1.00	50	00.	• 40000	26+39999	2174	
BSITIBN 162.0 50 10.00	50	00.	• 02650	4.29300	217A	

257.07178 FAILURES PER MILLION HOURS

172.00000 FAILURES PER MILLION HOURS

3889.9641 HBURS

MEAN TIME BETWEEN FAILURES EQUALS

DESIGN FAILURE RATE GOAL

TOTAL FAILURE RATE EQUALS

MOTOROLA, INC. FAILURE RATE DETERMINATION

49DEL POSITIONING SET	
	71. C
DATA DISPLY UNIT	TEMP 7
MODULE	
3995-113	17 340 Y1
PROJECT	DATE MAY 34.

			STREAD IN			ATLOYED LEX	• * •	
Samuel of S	COMPONENT DESCRIPTION	OTY	DTY PERCENT	FACTOR	FAILURE RATE	MILLIBY HRS.	SOURCE	NATES
	CAPACITOR, CER, CK	20.0		5.00	•02425	2.42500	217A	
	COILS RF	0	50	8.60	•22000	3.78400	2174	
Sactivity.	CONNECTOR, 10 PINS	T.		00.9	• 22200	•66603	217A	
	3504	2.0		1.00	•10000	• 20000	217A	
	INTEGRATED CIRCUIT, DISITAL	31.0		1.00	• 40000	12-40003	217A	
ú	* RESISTOR, FIXED CARBON COMPOSITION	5.0		10.00	• 02650	.13250	217A	
	RESISTOR, VARIABLE CARBON COMP.	1.0		50.00	•12650	6 • 32500	2174	
F		8.0		18.00	• 25000	0000006	217A	
The last		2.0		8.00	•82000	13.12000	217A	
58		0.4		1.00	•75050	• 30020	217A	
41	DIBDE, SILICON, 0-1 MATT	6.0		3.50	• 41000	8.61000	217A	
	RELAY, HALF CRYSTAL CAN	1.0		50.00	•00310	•15500	217A	
	INDICATOR, HP5082-7000	20.0		1.00	•80580	16-11600	SM-188	

73.23364 FAILURES PER MILLION HOURS 13654.9258 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FAILURE RATE EQUALS

J. Contract

Samuel S.

Finitos

FAILURE RATE DETERMINATION

Trement Property

DOU PAR SUP MEDEL POSITIONING SET	J . 12
MBDULE	
PRBJECT 3995-113	121.21 504 3140

		STRESS IN	~	BASIC	FAILURES PER	F . R.	
COMPONENT DESCRIPTION	QTA	PERCENT	FACTOR	FAILURE RATE	I.	SBURCE	VOTES
CAPACITOR, SLU TANT, CSR	0.9	S D	1.00	.70100	• 42060	217A-	
CAPACITOR, FOIL TANT, CL	2.0		8.00	•16750	2.68000	17	
COIL, AUDIO	1.0		10.00	•22750	2.27500	174	
DIBDE, SILICON, 0-1 AATT	15.0		3.50	•41000	21 • 52 4 9 9	217A-	
RELAY, HALF CHYSTAL CAN	1.0		ô	•00310	• 15560	171	
RESISTOR,	19.0		10.00	•02650	• 50350	217A-	
S. RESISTOR, FIXED METAL FILM	N		• 30	•24850	• 00149	174	
TRANSFORMER, POWER	1.0	20	10.00	• 22000	2.20000	217A -	
	4.0	20	8.00	•41000	13.12000	17A	
TRANSISTOR, SILICON APA, 1-50 WATT	1.0	20	8.00	•82000	6.56000	174	
		20	8.00	1.25000	30.00000	217A-	
	3.0	20	3.00	1.25000	11.25000	217A -	
CAPACITOR, CER, CK	3.0		2.00	• 00962	.14423	217A-	
CONNECTOR, 15 PINS	r.	20	00.9	•34300	1.02900		

91.86375 FAILURES PER MILLION HOURS 44.00000 FAILURES PER MILLION HOURS 10885.6836 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FAILURE RATE EQUALS DESIGN FAILURE RATE GOAL

APPENDIX F-4.2

TYPICAL OPERATION

RELIABILITY PREDICTION DATA SHEETS

POSITIONING SET AN/PSQ-101

ENVIRONMENT: VEHICLE MOUNTED GROUND

TEMPERATURE: +50°C

STRESS LEVELS: 30% (ASSUMED)

MODULE POWER CONVERTER PRBJECT 3995-113

50 C TEMP

DATE APR 20,171

MADEL A/T UNIT

NUTES F.R. SBURCE FAILURES PER MILLION HRS. STRESS IN K BASIC GTY PERCENT FACTOR FAILURE RATE COMPONENT DESCRIPTION

CAPACITOR, CEM, CK	3.0	30	5.00	04900•	00960•	217A
SLD TANT.	0.6	30	1.00	•17000	• 15300	217A
CAPACITOR, FOIL TANT, CL	5.0	30	8.00	• 08650	1 • 38 400	217A
S. COIL, RF	8.0	30	8 • 60	• 22000	4.54080	217A
DIBDE, SILICON, 0-1 AATT	8	30	3.50	• 25500	7 • 1 4000	217A
DIBDE, SILICON, 1-50 WATT	1.0	<u>ع</u> ن	12.00	• 43000	5 16000	217A
FILTER, FEED THRU	0.6	30	1.00	•05400	•21600	217A
SA RESISTOR, FIXED CARBON COMPOSITION	8.0	30	10.00	•00400	•03500	217A
RESISTOR, FIXED METAL FILM	0.4	30	• 30	•17000	• 20400	217A
TRANSFORME	1.0	ာဗ	10.00	• 22000	2.20000	217A
SILICON NPV. 0.	1.0	30	8.00	• 25500	2.04000	217A
TRANSISTUR,	1.0	30	8.00	•51000	4.08000	217A
SILICON PNP, O.	2.0	30	8.00	•67000	10.72000	2174
E. 0-1 MATT	1.0	30	3.00	•77000	2.31000	2174
CONNECTOR, 8 PINS	1.0	30	00.9	• 18200	1.09200	217A

41.36771 FAILURES PER MILLION HOURS TOTAL FAILURE RATE EQUALS

24173.4453 HBURS MEAN TIME BETWEEN FAILURES EQUALS

DESIGN FAILURE RATE GOAL

44.00000 FAILURES PER MILLION HOURS

MOTOROLA, INC. FAILURE RATE DETERMINATION

MODEL A/T UNIT	
	50. C
	TEMP
RF/1F	
MODULE	
PRBJECT 3995-113	DATE APR 20, 171
PRBJEC	DATE

COMPONENT DESCRIPTION	YT0	OTY PERCENT	FACTOR	BASIC FAILURE MATE	FAILURES PER MILLION HRS.	F.R. SBURCE	MATES
CAPACITUR, CEM, CK	15.0		5.00	.00640	(1) (1) (1) (1) (1) (1) (1) (1) (1) (1)	2174	
CAPACITOR, MICA, CM	0) (n)	15.00	.00071	• 02145	217A	
COIL, RF	1.0		8.60	• 22000	1 • 89200	217A	
CONNECTUR, RF	3.5		00.4	000000	• 56000	2174	
CONNECTOR, 15 PINS	.5		9	·34300	1.02900	217A	
INTEGRATED CINCUIT, LIVEAR	2.0		1.00	• 4 3000	2 • 00000	217A	
RELAY, HALF CRYSTAL CAN	1.0		50.00	•00310	▼15500	217A	
SA RESISTOR, FIXED CARBON COMPOSITION	19.0		10.00	00400	• 07600	217A	
	1.0		8.00	39 - 30000	7 • 86003	217A	-
S. DIBDE, HUT CARRIER	4.0		3.50	• 65000	2.73000	217A	
S. TRANSFORMER, KF	2.0		10.00	• 22000	1 • 32000	217A	
CAPACITOR, VAR AIR, CT	2.0		1.00	•03200	•07000	217A	

18-19342 FAILURES PER MILLION HOURS 19.00000 FAILURES PER MILLION HOURS 54964.9219 HBURS MEAN TITE BETWEEN FAILURES EQUALS TOTAL FAILURE RATE EQUALS DESIGN FAILURE RATE GOAL

NOTE1: FACTOR OF 0.1 APPLIED TO FAILURE RATE DUE TO NO FIELD ADJUSTMENTS

- Total

A STORY OF

Total Control

MOTORBLA, INC. FAILURE RATE DETERMINATION		
	RBLA, I	TERMINAT

MODULE POWER AMPLIFIER PRBJECT 3995-113

TEMP DATE APR 20,171

MEDEL AZT UNIT

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		> 1 C	STRESS IN	A	BASIC FATE OF BATE	FAILURES PER	F . R .	1
			בייין.		TAILUNE TAIL	SELECTOR TASE	פסטוריב	SOIES
	CAPACITON, CER, CK	61.0		5.00	0+900•	1.95200	217A	
S	COIL, RF	24.0		8 • 60	• 22000	13.62241	2174	
	CONNECTOR, RF	1.5	30	4.00	20240.	• 24000	217A	
	DIGOE, HOT CARRIER	3.0		3.50	•65000	6.82500	217A	
		8.0		3.50	• 25500	7 • 1 4 0 6 0	217A	
Š		33.0		10.00	004000	•13200	217A	
	TRANSFORMER, KF	1000		10.00	• 22000	22.00000	217A	
S	S3 TRANSISTUR, FIELD EFFECT	0.6		8.00	•67000	14.47200	217A	
	TRANSISTOR, SILICON LPL	1.0		8.00	• 25500	2.04000	217A	
Sz		9.0		8.00	•51000	11.01601	217A	
F	CONNECTOR, 36 PINS	ស		00.9	1.22500	3.67500	217A	
-63								

83.11436 FAILURES PER MILLION HOURS TOTAL FAILURE RATE EQUALS

MEAN TIME BETWEEN FAILURES EQUALS 12031.6133 HOURS

95.00000 FAILURES PER MILLIUN HOURS DESIGN FAILURE RATE GOAL

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MADEL A/	
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XMTR MBDULATBR	TEMP
MODULE	
CT 3995-113	AP 20, 171
PRBJECT	DATE

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			STRESS IN		BASIC	FAILURES PER	5
	COMPONENT DESCRIPTION	OTY	OTY PERCENT	FACTBR	FAILURE RATE	MILLIBN HRS.	SHURCE
non-	CAPACITOR. CER. CK	6.0		0	27700		
					0+000+	COUCT.	K1/\
	CAPACITUM, SLD TANT, CSR	0.0		1.00	.17000	• 03400	217A
	COIL, RF	5.0		8 • 60	• 22000	3.78400	217A
	DIBDE, HOT CARRIER	8		3.50	• 65000	18-20000	217A
	DIBDE, SILICBN, U-1 AATT	10.0		3.50	• 25500	8 92500	2174
	INTEGRATED CIRCUIT, LINEAR	0.0		1.00	00004	680000	217A
	RELAY, HALF CRYSTAL CAN	3.0		50.00	• 00310	• 46500	2174
84		30.0	30	10.00	00400	• 12000	217A
		4.0		10.00	•22000	8 • 80000	217A
Ś	SA TAANSISTUR, SILICON APA, D-1 MATT	10.0		8 • 00	• 25500	6.12003	217A
L. Theorem	ZENER DIBDE, 0-1 HATT	1.0		3.00	•77000	2.31000	217A

49.74994 FAILURES PER MILLION HOURS TOTAL FAILURE RATE EQUALS

20100.5234 HBURS MEAN TIME BETWEEN FAILURES EQUALS

52.00000 FAILURES PER MILLION HOURS DESIGN FAILURE RATE GOAL

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A contract to

MADEL AZT UNIT MODULE FREG SYN 1 (XMTR) PRBJECT 3995-113

50° C TEMP DATE APR 20, 171

NATI FOLGO CONTINUO DE CONTINU	0, ≯ 40	STRESS IN	A TAN	BASIC	FAILURES PER	F. 8.	1
	•	1.12.1		コート コートー	PERION THE	SUCKE	A LES
	22.0		5.00	.00640	•70400	217A	
CAPACITBK, MICA, CM	16.0	3 ₀	15.30	17000	•17163	217A	
C01L, AF	8		8.60	•22000	15.13600	217A	
S. DIODE, HOT CARRIER	15.0		3.50	• 65000	8 • 19000	217A	
DIBDE, SILICBN, 0-1 MATT	2.0		3.50	•25500	4.46250	217A	
INTEGRATED CIRCUIT, LINEAR	5.0		1.00	00000	• 80000	217A	
SA RESISTOR, FIXED CARBON COMPOSITION	57.0		10.00	00400	• 22800	217A	
TRANSISTOR, SILICON JPN, 0-1 WATT	0.9		8.00	• 25500	12-24000	217A	
A TRANSISTUR, SILICON PND, 0-1 MATT	0 N		8.00	•67000	10.72000	217A	
9 TRANSFORMER, KF	4.0		10.00	• 22000	3 - 30000	217A	
G RESISTOR, VARIABLE, 10-TURN	1:0		2.00	1.51000	3.02000	SM-188	

64,47203 FAILURES PER MILLIBN HOURS 66.00000 FAILURES PER MILLION HOURS 15510.6016 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FAILURE RATE EQUALS DESIGN FAILURE RATE GOAL

YODEL A/T UNIT MODULE FREG SYN 2 (REC.) PRBJECT 3995-113

APR 20, 171 DATE

50° C TEMP

		STRESS IN	~	BASIC	FAILURES PER	. Y.	
COMPONENT DESCRIPTION	OTY	PERCENT	FACTOR	FAILURE RATE	MILLIBY HRS.	SOURCE	NUTES
CAPACITUM, CEN, CK	22.0	30	5.00	.00640	•70400	217A	
CAPACITBR, MICA, CM	16.0	30	15.00	•03071	•17160	217A	
SS COIL, RF	8	30	8.60	• 22000	4.54080	217A	
S. DIODE, HOT CARRIER	12.0	30	3.50	•65000	8 19000	217A	
DIBDE, SILICBN, U-1 AATT	2.0	30	3.50	• 25500	4 • 46250	217A	
INTEGRATED CINCUIT, LIVEAR	2.0	30	1.00	• 40000	•80000	217A	
S. RESISTOR, FIXED CARBON COMPOSITION	57.0	30	10.00	00400	• 22800	217A	
. 0-1	0.9	30	8.00	• 25500	12.24000	217A	
TRANSISTOR, SILICON PAD. 0-1 MATT	2.0	30	8.00	•67000	10.72000	217A	
TZANSFORMER	0.4	30	10.00	•22000	8 • 80000	217A	
RESISTOR, VARIABLE, 10-TURN	1.0	20	2.00	1.58500	3.17000	SM-188	
S CONNECTOR, RF	3.0	30	4.00	000+0•	• 48000	217A	
CONNECTOR, 15 PINS	٠ گ	30	00.9	•34300	1.02900	217A	

55.53581 FAILURES PER MILLION HOURS TOTAL FAILUNE RATE EQUALS

18006.3984 HBURS MEAN TIME BETWEEN FAILURES EQUALS

DESIGN FAILURE RATE GRAL

66.00000 FAILURES PER MILLION HOURS

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MODULE CARRIER 19/VCB PR9JECT 3995-113

MODEL AZT UNIT

DATE AP4 20,171

50 °C TEMP

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COMPONENT DESCRIPTION	TTO	PERCENT	FACTBR	FAILURE RATE	MILLION HAS.	SOURCE	NUTES
TO SALA SAS AND TO SAST	6	ć		300	ľ	•	
	3	2		00000	700.00	-	
	72.0	30	5.00	04900	2.30403	-	
CAPACITOR, MICA, CM	14.0	3 <u>0</u>	•	• 000071	•15015	2174	
S3 COIL, RF	0.9	30	8	055000			
		30	•	000000	4800	4 -	
CONNECTOR, 15 PINS		30	•	000 WE	1.029.00	217	
DIBDE, SILICON, 0-1 4ATT	5.0	30	3.50	•25500	4.46253	2174	
INTEGRATED CINCUIT, DIGITAL	3.0	30	•	00004	1.20000		
INTEGRATED CINCUIT, LINEAR	19.0	30	1.00	00004.	7 • 603.3		
S& RESISTBRA FIXED CARBAN CUMPOSITION	80.0	30		00400	• 32000	217A	
RESISTOR, FIXED METAL FILM	27.0	30	• 30	•17000			
NN VAR. LEAD SCREW	3.0	30	18.00	009600	-	4	
S3 TRANSISTUR, SILICON NPV. 0-1 WATT		30	•	• 25500	•	-	
	•	30	3.00	•77000	00066-9	-	
I DIGDE, HOT CARRIER	0 • +	30	3.50	•65000	•	-	
	8.0	30	10.00	•22000	0000++	-	
CRYSTAL, GUARTZ	•	30	1.00	• 05000	• 06000	-	
	0.4	30	5.00	•00625	• 12500		
	•	30	20.00	•05850	1.17000		
, VAR CER, CV	1.0	30	1.00	•03200	•03500		
S4 RESISTOR, FIXED METAL FILM	•	30	• 30	•17000	•00102		

52.46315 FAILURES PER MILLION HOURS 19060.9961 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FAILURE RATE EQUALS

DESIGN FAILURE RATE GBAL

54.00000 FAILURES PER MILLIUN HOURS

MBDEL A/T UNIT	
	50° C
CODE DETECTOR	TEMP
MODULE	
PR6JECT 3995-113	DATE APR 20,171

		3	STRESS IN K	Y	BASIC	FAILURES PER	F . R.	
	COMPONENT DESCRIPTION		FERCEN	* ACTOR	FAILURE MATE	TILLIBN HKS.	SBURCE	NOTES
	CAPACITON, CEN, CK	0.94		5.00	0+900•	1.47263	217A	
	CAPACITOR, MICA, CM	•		15.00	1,0000	• 04290	217A	
	CONVECTOR, 15 PINS	ហ		6.30	•34300	1 • 02900	217A	
S	S. DIBDE, SILICON, 0-1 MATT	7.0	30	3.50	•25500	1.87425	217A	
	INTEGRATED CIRCUIT, DISITAL	3.0		1.00	00004.	1.20000	217A	
S	INTEGRATED CIRCUIT, LINEAR	19.0		1.00	00004.	2.28000	217A	
	RESISTOR, FIXED METAL FILM	28.0		• 30	•17000	1.42800	217A	
	RESISTOR, WW VAR. LEAD SCREW ACT.	1.0		18.00	00960	1.72800	RADC	
1	TRANSISTOR, SILICON MPN. 0-1 MATT	1.0		8.00	.25500	2.04000	217A	

13.09411 FAILURES PER MILLION HOURS TOTAL FAILURE RATE EGUALS

76370-1875 HBURS MEAN TIME BETWEEN FAILURES EQUALS DESIGN FAILURE RATE GBAL

16.00000 FAILURES PER MILLION HOURS

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CACU (DIGITAL)	TEMP
CACU	
MODULE	
PRBJECT 3995-113	APA 20.171
1	APA
PRBJEC	DATE

COMPONENT DESCRIPTION	710	STRESS IN	FACTBR	BASIC FAILJRE RAFE	FAILURES PER MILLIBY ARS.	F.R. SBURCE	NUTES
CAPACITUM, CEM, CK	30.0		5.30	0.000	00096•	217A	
S4 INTEGRATED CIRCUIT, DISITAL	71.0		1.00	0000+•	2 • 8 4 0 0 0	2174	
RELAY, HALF CRYSTAL CAV	1.0		50.00	•00310	•15500	217A	
S. RESISTOR, FIXED CARBON COMPOSITION	54.0		10.00	00400	•21600	217A	
CAPACITOR, MICA, CM	0.9	30	15.00	• 00071	• 06435	217A	
COIL, RF	3.0		8.60	• 22000	5.67600	217A	
CONNECTOR, RF	0.9		00.4	00040*	• 96000	217A	
CONNECTOR, 36 PINS			00.9	1.22500	3.67500	217A	
F							

20.00000 FAILURES PER MILLION HOURS 68745.9375 HBURS MEAN TIME BETWEEN FAILURES EQUALS DESIGN FAILURE RATE GOAL

14.54630 FAILURES PER MILLION HOURS

TOTAL FAILURE RATE EQUALS

MADEL 4/T UNIT 50° C MBDULE CL9CK 1G DETECT93 TEMP PRBJECT 3995-113 DATE APR 20, 171

COMPONENT DESCRIPTION	QTY	STRESS IN	FACTBR	BASIC FAILJRE RAIE	FAILURES PER MILLION HRS.	F.R. SBURCE	NOTES
CAPACITOR, VAR AIR, CT	1.0	30	1.30	•03500	•0350°	217A	
CAPACITON, CEN, CK	36.0	30	5.00	04900 •	N	217A	
CAPACITOR, MICA, CM	10.0	30	15.00	• 00071	•10725	217A	
SJ COIL, RF	0.9	30	8 • 60	• 22000	3.40560	217A	
CONNECTOR, RF	3.0	30	00.4	00040.	• 48000	217A	
CONNECTOR, 15 PINS	ហ្វ	30	6.30	•34300	1.02900	217A	
DIGDE, SILICON, 0-1 AATT	5.0	30	3.50	• 25500	1.78500	217A	
INTEGRATED	12.0	30	1.00	00004.	4.80000	217A	
S& RESISTBR, FIXED CARBSY COMPOSITION	48.0	ع _ا ن	10.00	00400	•19200	217A	
RESISTOR, FIXED METAL FILM	13.0) ()	• 30	.17000	•66300	. 217A	
RESISTOR, WW VAR. LEAD SCREW ACT.	1.0	30	18.00	00960.	•	RADC	
SS TRANSFORMER, RF	0.9	.30	10.00	•22000	3.96000	217A	
	5.0	30	8.00	• 25500	4.08000	217A	
I ZENER DIODE, 0-1 WATT	1.0	30		•77000	2,31000	217A	
DIBDE, HOT CARRIER	0.4	30	3.50	•65000	9.10000	217A	
CAPACITOR, T C CER, CC	**	30	2.00	•00625	•12500	2174	
CRYSTAL, QUARTZ	2.0	<u>ع</u> ر	1.00	• 05000	000+0.	217A	

HOURS		HOURS
ER MILLIBN	URS	R MILLION
S	9	P
34.99174 FAILURES PER MILLION HOURS	28578.1680 HBURS	36.00000 FAILURES PER MILLIUN HBURS
34.	EQUALS	36.(
TOTAL FAILURE RATE EQUALS	MEAN TIME BETWEEN FAILURES EQUALS	DESIGN FAILURE RATE GOAL
RATE	EEN F	RATE
UKE	BETW	LURE
FAIL	146	FAI
BTAL	EAN T	ES I GA
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MODULE CLOCK PHASE CONTROL

MBDEL A/T UNIT PRBJECT 3995-113

DATE AP4 20, 171

50 C TEMP

			STRESS IN	¥	BASIC	FAILURES PER	A. A.	
	COMPONENT DESCRIPTION	GIY	PERCENT	FACTBR	FAILURE RATE	MILLION 185.	SBURCE	NUTES
	CAPACITUM, CEM, CK	38.0		5.33	0.00640	1.21600	217A	
	CAPACITOR, MICA, CM	4	30	15.00	• 00071	- C4890	217A	
Sa	COIL, RF	5.0		8.60	• 22000	2 · 838 U.D	217A	
	DIBDE, SILICON, 0-1 AATT	1.0		3.50	• 25500	•89250	217A	
	INTEGRATED CINCUIT, DISITAL	4.0	3 0	1.00	00004.	1.60000	217A	
	INTEGRATED CINCUIT, LINEAR	12.0		1.00	00004•	4 • 80000	217A	
š	RESISTOR, FIXED CARBON COMPOSITION	28.0		10.00	00+00•	•11200	217A	
	RESISTOR, FIXED METAL FILM	10.0		• 30	•17000	•51000	217A	
	RESISTBR. WW VAR. LEAD SCREW ACT.	1.0		16.00	00960•	1.72860	KADC	
53		5.0		10.00	• 22000	3.30000	217A	
		1:0		8.00	• 25500	2.04000	217A	
F-		0.4		3.50	• 65000	9.10000	217A	
71		8.0		2.00	• 00625	• 25000	217A	
		4.0		1.00	•05000	08000	2174	

28.50932 FAILURES PER MILLIBN HBURS 30.00000 FAILURES PER MILLIUN HOURS 35076-2422 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FALLURE RATE EQUALS DESIGN FAILURE RATE GOAL

MODEL POSITIONING SET	
RTJ CABLE HARNESS	TEMP 50. C
MEDULE	
PR6JECT 3995-113	DATE AP4 20,171

18.0 30 4.00 .04000 2.88000 2.0 30 6.00 .18200 2.18400		FAILURE RATE MILLION ARS.	HRS. SBURCE	ABTES
8 PINS 2.0 30 6.30 .18200 2.18403	30 4+39			
COCABACT COCACA COCACA COCACA COCACACA COCACACACA	30 6.30		217A	
	30 6•30			
36 PINS 1.5 30 6.00 1.22500 3.30750	30 6.00			

HOURS		HOURS
MILLIBN	10	ILLION
S PER	5 HOURS	S PER ?
10.22370 FAILURES PER MILLIBN HBURS	97811.9375 HBURS	12-00000 FAILURES PER MILLION HOURS
10.2		12.00
TOTAL FAILUNE RATE EGUALS	MEAN TIME BETWEEN FAILURES EQUALS	DESIGN FAILURE RATE GOAL

MBDULE ACOU-DPU PRBJECT 3995-113

MADEL POSITIONING SET

Section 2

DATE APR 20,171

50. C TEMP

TES

		O)	STRESS IN	Y	BASIC	FAILURES PER	F. K.	
	COMPONENT DESCRIPTION	VT0	PERCENT	FACTOR	FAILURE RATE	MILLIBY 188.	SBURCE	DO
	CAPACITER, CEN, CK	68.0	30	2.00	04900•	2.17603	217A	
	CAPACITUR, T C CER, CC	8.0	30	5.00	• 00625	•06253	217A	
	_	20.0	30	15.00	• 00071	•21450	217A	
	CAPACITOR, SLD TANT, CSR	5.0	30	1.00	•17000	• 08200	217A	
	æ	1.0	3Ū	10.00	• 20000	2.00000	217A	
S	COIL, RF	3.0	30	8.60	• 22000	1.70280	217A	
S	INTEGRATED CINCUIT, DISITAL	41.0	30	1.00	00004.	4.92000	217A	
S	INTEGRATED CIRCUIT, LIVEAR	12.0	30	1.00	00004.	1.44000	217A	
\$	RESISTAR, FIXED CARBON COMPOSITION	54.0	30	10.00	00+00•	•21600	217A	
	RESISTORY FIXED METAL FILM	8.0	<u>ع</u>	• 30	.17600	-4080D	217A	
	TRANSFORMER, MF	0.0	30	10.00	• 22000	00004 • 4	217A	
F-7		1.0	30	8•00	• 25500	2.04000	217A	
3								

19.66473 FAILURES PER MILLION HOURS TOTAL FAILURE RATE EQUALS

50852.4531 HBURS MEAN TIME BETWEEN FAILURES EQUALS 21.00000 FAILURES PER MILLION HOURS DESIGN FAILURE RATE GOAL

50.0
TEMP
DATE APA 20, 171

COMPONENT DESCRIPTION	710	PERCENT	FACTBR	FAILURE RATE	MILLION TRES	F.R.	NOTES
CAPACITOR, SLU TANT, CSR	0.9		1.00	.17000	•1020D	217A	
CAPACITORS FULL TANTS CL	2.0	30	8 • 00	• 03650	1+38400	217A	
COIL, AUDIO	1.0		10.00	• 20000	2.00000	217A	
DIBDE, SILICON, 0-1 WATT	15.0		3.50	•25500	13,38750	217A	
RELAY, HALF CHYSTAL CAN	1.0		50.00	.00310	•15500	217A	
S. RESISTOR, FIXED CARBUN CUMPUSITION	19.0		10.00	00*00	•07600	2174	
_	2.0		• 30	•17000	•00108	2174	
	1.0		10.00	• 22000	2.20000	217A	
TRANSISTUR, SILICON JPN, 0-1 JATT	C • 4		8.00	• 25500	8 • 16000	217A	
TRANSISTUR, SILICON APA, 1-50 HATT	1.0		8.00	.51000	4.08000	217A	
SS TRANSISTUR, SILICON PNP. 0-1 HATT	3.0		8.00	•67000	4.82400	217A	
ZENER DIBDE, 0-1 MATT	3.0		3.00	•77000	6.93000	217A	
I CAPACITUR, CER, CK	3.0		2.00	04900•	• 09600	2174	
CONNECTOR 15 PINS	ຜູ		6.00	•34300	1.02900	2174	

44.42442 FAILURES PER MILLIBN HBURS 46.00000 FAILURES PER MILLIBN HOURS 22510.1367 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FAILURE RATE EQUALS DESIGN FAILURE RATE GOAL

S. Statement S.

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MADEL PASITIONING SET	
	U
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DPU WORD CONTROL	TEMP
Ç	
MODULE	
PKBJECT 3995-113	DATE APR 20, 171

COMPONENT DESCRIPTION) }	STRESS IN GTY PERCENT	FACTBR	BASIC FAILURE RATE	FAILURES PER MILLIBY ARS.	F.K. SBURCE	NOTES
CAPACITUR, CER, CK	15.0		5.00	.00640	0.000	2174	
S3 CONNECTOR, 36 PINS	1:00	<u>ه</u>	00.9	1.22500	2+23503	217A	
S. INTEGRATED CINCUIT, DIGITAL	44.0		1.00	00004.	5.28000	217A	
S. RESISTOR, FIXED CARBON CUMPOSITION	5.0		10.00	00400	•05200	217A	

MILLION HOURS		ILLION HOURS
PER	HBURS	PER
7.98499 FAILURES PER MILLION HOURS	125235.0000	13.00000 FAILURES PER MILLIBN HBURS
7.	EQUALS	13.0
TOTAL FAILURE RATE EQUALS	MEAN TIME BETWEEN FAILURES EQUALS 125235.0000 HBURS	DESIGN FAILURE RATE GOAL

MBTBRBLA, INC. FAILURE RATE DETERMINATION

SET		S PER F.R.
MODEL POSITIONING SET		FAILURE
HEDEL P		STRESS IN K BASIC
CTRL	50° C	¥.
MODULE DPJ MSG BUTPUT CTRL	TEMP	NI SS
DPU MS		STRE
MODULE		
PKBJECT 3995-113	DATE APA 20, 171	
PRBJE	DATE	

LLIBN HBURS	
8.42899 FAILURES PER MILLION HOURS	638.1875 HBURS
8 • 42899	EGUALS 118
TOTAL FAILURE RATE EQUALS	MEAN TIME BETWEEN FAILURES EGUALS 118638.1875 HOURS
TBTAL	YEAN T

13.00000 FAILURES PER MILLION HOURS

DESIGN FAILURE RATE GOAL

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MODEL POSITIONING SET	
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PR9JECT 3995-11	DATE APR 20.
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COMPONENT DESCRIPTION	VTO	STRESS IN K OTY PERCENT FACTOR	K FACT93	BASIC FAILURE RATE	FAILURES PER MILLIBY HRS.	F.R. SBURCE	NOTES
CAPACITOR, CEM, CK CONNECTOR, 36 PINS INTEGRATED CIRCUIT, DISITAL RESISTOR, FIXED CARBON COMPOSITION	15.0 46.0 6.0	2000 2000 2000 2000	100000	.00640 1.22500 .40000	・+&」。 2・8つ5い 5・8つ5い 5・52つい 02400	217A 217A 217A	

8.22899 FAILURES PER MILLION HOURS TOTAL FAILURE RATE EQUALS

MEAN TIME BETWEEN FAILURES EQUALS 121521.6250 HBURS

13.00000 FAILURES PER MILLIUN HOURS DESIGN FAILURE RATE GOAL

MEDEL POSITIONING SET	
n۲	50 · C
DPU COMMAND DECODE:	IO
0	TEMP
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PRBJECT	DATE APR 20, 171

COMPONENT DESCRIPTION	YTO	OTY PERCENT	FACTBR	FAILURE RATE	MILLION HRS.	SOURCE	NOTES
CAPACITOR, CER, CK	14.0		5.00	04900•	.44803	217A	
S. CONNECTUR, 36 PINS	1.0	30	6.00	1.22500	2 - 20500	217A	
SA INTEGRATED CINCUIT, DIGITAL	44.0		1.00	00004.	5.28000	217A	
S+ RESISTAR FIXED CARBON COMPOSITION	20.0		10.00	00+00	• 08000	217A	
CAPACITOR, SLD TANT, CSR	1.0		1.00	•17000	•01700	217A	

HOURS		HOURS
MILLION	'0	11LLION
PER	HBUR	PER
8.C2997 FAILURES PER MILLION HOURS	124533.4375	13.00000 FAILURES PER MILLION HOURS
8.02	EGUALS	13.000
EGUALS	AILURES	GBAL
TOTAL FAILURE RATE EGUALS	MEAN TIME BETWEEN FAILURES EQUALS 124533.4375 HOURS	DESIGN FAILUNE RATE GOAL
191	MEA	DES

MOTOROLA, INC. FAILURE RATE DETERMINATION

former .

MODEL POSITIONING SET	
	50° C
DPU MEMBRY	TEMP
MBDULE	
PR8JECT 3995-113	DATE APR 20, 171

COMPONENT DESCRIPTION	QTY	GTY PERCENT	FACTBR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SBURCE	NUTES
CAPACITUR, GLASS, CY	5.0		18.00	• 02300	2.07000	217A	
	34.0	30	5.00	04900•	1.08800	217A	
	7.0		1.00	•17000	.11900	217A	
CONNECTOR, 36 PINS	េះ		6.30	1.22500	3.67503	217A	
SA INTEGRATED CIRCUIT, DIGITAL	29.0		1.00	00004.	7 • 08000	217A	
SA RESISTORS FIXED CARBON COMPOSITION	18.0		10.00	00400•	• 07200	217A	
SA RESISTOR, FIXED METAL FILM	0.4		•30	•17000	•0050	217A	
INTEGRATED CIRCUIT, LINEAR	8		1.00	• 40000	3.20000	217A	

HOURS		HOURS
MILLION	ş	MILLION
PEF	H	PER
17.30602 FAILURES PER MILLION HOURS	MEAN TIME BETWEEN FAILURES EQUALS 57783.3750 HOURS	22.00000 FAILURES PER MILLION HOURS
• 3060	S	00000
17	EDUALS	22.
TOTAL FAILURE RATE EQUALS	ILURES	GBAL
TE E	N FA	RATE
RE R	ETWE	URE F
FAILU	1.4E 8	FAIL
BIAL	LAN T	DESIGN FAILURE RATE GOAL
	2.,	9

MOTORULA, INC. FAILURE RATE DETERMINATION

		F.R. SBURCE
49DEL POSITIONING SET		FAILURES PER MILLIBY HRS.
490EF 988	U	BASIC AILJRE RATE
MBJULE CABLE HARNESS-JPU	TEMP 50. C	STRESS IN K BASIC GTY PERCENT FACTOR FAILJRE RAFE
PRBJECT 3995-113 M	DATE APR 200'71	COMPONENT DESCRIPTION

NOTES

217A 217A 217A 217A

.32000 1.02900 15.43501 1.45800

.04000 .34300 1.22500

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CONNECTOR, RF
CONNECTOR, 15 PINS
CONNECTOR, 36 PINS
CONNECTOR, 20 PINS

HOURS		Caller
11119N		2
PER #	HBURS	Dr.D. M.T.
18.24200 FAILURES PER MILLION HOURS	54818.5352 HBURS	SAUGH WEITTER BER MITTEN HBIRS
4200 F	54818	DOO FA
18.2		97.00
TOTAL FAILURE RATE EGUALS	MEAN TIME BETWEEN FAILURES EQUALS	DESIGN FAILURE RATE GRAI
RATE	VEEN F	RATE
ILURE	E BET	A III URS
FA	114	Z
TOTAL	MEAN	DEST

Transcript &

A contract of

MODEL POSITIONING SET MEDULE CONTROL PANEL-DAU PRBJECT 3995-113

TEMP DATE APA 20, 171

50 C

8.60 .22000 11.35200 1.00 .10000 .10000 18.00 .25000 62.10001 5.00 1.22500 7.35000 1.00 .40000 26.39999	OTY PERCENT
1.00 18.00 5.00 6.00 1.22500 1.000 1.000	30
18.00 5.00 .00640 6.00 1.22500	30
5.00 .00640 6.00 1.22500 1.00 .40000	30
1.00 1.22500	30
1.00	30
00400	30
00+00+	30

108-33397 FAILURES PER MILLIBN HBURS TOTAL FAILURE RATE EGUALS

9230-7148 HBURS MEAN TIME BETWEEN FAILURES EQUALS

DESIGN FAILURE RATE GOAL

172.00000 FAILURES PER MILLIUN HOURS

L POSITIONING SET	
TIS64	
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DATA DISPLY UNIT	-
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.00640 .22000 .22000 .22200 .20200 .20200 .20000 .20000 .00400 .02000	COMPONENT DESCRIPTION	710	STRESS IN PERCENT	FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION 148.	SOURCE	NOTES
COPIL, RF CONNECTOR, 10 PINS CONNECTOR								
CONNECTOR, 10 PINS -5 30	CAPACITOR, CER, CK	20.0		5.00	0.900.	00049.	217A	
CONNECTOR, 10 PINS CONNECTOR CONN	COIL, RF	2.0		8.60	• 22000	3.78400	217A	
FUSE INTEGRATED CIRCUIT, DIGITAL 11.0 30 1.00 .10000 .20000 RESISTOR, FIXED CARBON CUMPOSITION 5.0 30 10.00 .00000 .02000 RESISTOR, VARIABLE CARBON COMP. 2.0 30 18.00 .00000 .25000 TAANSISTOR, VARIABLE CARBON COMP. 2.0 30 18.00 .25000 9.00000 CAPACITOR, SLLICON WPW, 1-50 MATT 2.0 30 8.00 .25500 8.16000 RELAY, HALF CRYSTAL CAN 2.0 30 30 3.50 .25500 1.5500 RELAY, HALF CRYSTAL CAN 2.0 30 1.00 .80580 16.11600 1.001	CONNECTOR, 10 PINS	•		00.9	.22200	• 66600	217A	
### SISTOR. FIXED CARBON CUMPOSITION	JS04	2.0		1.00	•10000	• 20000	217A	
### STOR, FIXED CARBON CUMPOSITION 5.0 30 10.00 .00400 .02000 .02000 .10000 .10000 .10000 .10000 .10000 .10000 .10000 .25000 .10000 .25000 .25000 .25000 .1000 .17000 .17000 .17000 .17000 .15000 .170000 .170000 .170000 .170000 .170000 .170000 .170000 .170000 .1700000 .170000 .170000 .170000 .170000 .170000 .1700000 .1700000 .170000 .170000 .1700000 .1700000 .1700000 .1700000 .17000000 .1700000 .1700000 .17000000 .1700000 .170000000000	INTEGRATED CIRCUIT, DIGITAL	31.0		1.00	00000	12.40000	217A	
#ESISTOR, VARIABLE CARBON COMP. 1.0 30 50.00 .10030 5.00000 5.41TCM, TOGGLE OR PUSHBUTTON 2.0 30 18.00 .25000 9.00000 TAANSISTOR, SILICON WPW, 1-50 hATT 2.0 30 8.00 .17000 8.16000 CAPACITOR, SLO TANT CSR 4.0 30 3.50 .17000 .06803 5.35503 MELAY, HALF CRYSTAL CAN 1.0 30 50.00 .00310 .15500 16.11600 1001000 10010000000000000000		5.0		10.00	00+00•	• 05000	217A	
Switch, Toggle OR PUSHBUTTON 2.0 30 18.00 .25000 9.00000 TRANSISTOR, SILICON WPW, 1-50 LATT 2.0 30 8.00 .51000 8.16000 CAPACITOR, SLD TANT, CSR 4.0 30 1.00 .17000 .06800 DIODE, SILICON, 0-1 AATT 6.0 30 3.50 .25500 5.35500 MELAY, MALF CRYSTAL CAN 1.0 30 50.00 .00310 .15500 16.11600 100000 100000000000000000000	RESISTOR, VARIABLE CARBON COMP.	1.0		50.00	10000	5.00000	217A	
TRANSISTOR, SILICON WPW, 1-50 MATT 2-0 30 8-00 -51000 8-16000 CAPACITOR, SLO TANT, CSR 4-0 30 1-00 -17000 -06800 CAPACITOR, SLICON, 0-1 MATT 6-0 30 3-50 -25500 5-35500 MELAY, MALF CRYSTAL CAN 1-0 30 50-00 -00310 -15500 15500 100100000000000000000000	SAITCH, TOGGLE OR PUSHBUTTON	2.		18.00	• 25000	9.00000	217A	
CAPACITOR, SLO TANT, CSR 4.0 30 1.00 .17000 .06800 DIODE, SILICON, 0-1 MATT 6.0 30 3.50 .25500 5.35500 RELAY, MALF CRYSTAL CAN 1.0 30 50.00 .00310 .15500 INDICATORAMPORE-7000 20.0 30 1.00 .80580 16.11600		2.0		8.00	•51000	8 • 16000	2174	
DIBDE, SILICBN, 0-1 4ATT 6.0 30 3.50 .25500 5.35500 RELAY, HALF CRYSTAL CAN 1.0 30 50.00 .00310 .15500 INDICATOR, HP5082-7000 20.0 30 1.00 .80580 16.11600		•		1.00	•17000	•06800	2174	
1.0 30 50.00 .00310 .15500 20.0 30 1.00 .80580 16.11600 1	_	9.9		3.50	.25500	5-35500	217A	
20.0 30 1.00 .80580 16.11600	RELAY, HALF CRYSTAL CAN	1:0		50.00	•00310	•15500	217A	
	INDICATOR.HP5082-7000	20.0		1.00	.80580	16-11600	SH-188	

HOURS		HOURS
HILLION	S	MILLION
PER	HOUR	PER
61.56395 FAILURES PER MILLION HOURS	16243.2695 HOURS	127.00000 FAILURES PER MILLIUN HOURS
61.5	EDUALS	127.00
TOTAL FAILUNE RATE EQUALS	MEAN TIME BETWEEN FAILURES EQUALS	DESIGN FAILURE RATE GOAL
RATE	EEN F	RATE
URE	BETW	ILURE
FAIL	311	N FA
TOTAL	NEAN	01830

49DEL POSITIONING SET 50. C TEMP MODULE DOU PWK SUP PRBJECT 3995-113 DATE APT 200171

			STRESS IN	~	BASIC	FAILURES PER	F.R.	
	COMPONENT DESCRIPTION	GTY	PERCENT	FACTBR	FAILURE RAIE	MILLIBN ARS.	SOURCE	NOTES
	CAPACITUM, SLU TANT, CSR	0.9	30	1.00	•17600	•10200	217A	
	CAPACITOR, FOIL TANT, CL	2.0	3 <u>.</u>	8.00	.03650	1.38400	217A	
	9100	1.0		10.00	•20000	2.00000	217A	,
S	DIBDE, SILICEN, 0-1 AATT	15.0		3.50	• 25500	4.01625	217A	
	RELAY, HALF CHYSTAL CAL	1.0		50.00	•00310	• 15500	217A	
\$	RESISTOR, FIXED CARBON COMPOSITION	19.0		10.00	00400	009200	217A	
3	RESISTOR, FIXED METAL FILM	2.0		• 30	•17000	•00102	-	
	TRANSFORMER, POWER	1.0	30	10.00	• 22000	2.20000	-	
	TRANSISTUR, SILICON APLA 0-1 MATT	4	ာင	8.00	. 25500	8 16000	217A	
	TRANSISTUR, SILICON VPN, 1-50 WATT	1.0	30	6.60	•51000	4.08000	-	
S	TRANSISTUR, SILICEN PNP. 0-1 MATT	3.0	30	8.00	00029•	4.82400	217A	
I	ZENER DIBDE	3.0	30	3.00	•77000	6.93000	217A	
r-	CAPACITOR, CER, CK	3.0	30	2.00	049000	009600	217A	
83	CONNECTOR, 15 PINS	• •	30	6.00	•34300	1.02900	217A	

35.05316 FAILURES PER MILLION HOURS 28528.0937 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FALLUNE RATE EQUALS

44.00000 FAILURES PER MILLIUN HBURS DESIGN FAILURE RATE GBAL

MOTORIA INC. FAILURE RATE DETERMINATION

MADEL POSITIONING SET	50• C
	50
CRYSTAL 9SC	TEMP
MODULE	
PR6JECT 3995-113	DATE APR 20, 171

		(J)	TRESS IN	¥	8 A \$1C	ATLURES P	2	
	COMPONENT DESCRIPTION	OTY	PERCENT	FACTOR	FAILURE RAIE	LIBN HAS	SBURCE	NOTES
	•	5.0	30	18.00	• 52300	70	17	
	CAPACITOM, CER, CK	29.0	30	•	04900	.928	• -	
		•	3 C	5	• 00071	1	17	
		1.0	30	•	• 25850	70	-	
	MYLA	•	30	ò	.00125	•0500	-	
	SLO TANT	•	30	•	•17000	3	17	
	CAPACITOR, VAR CER, CV	••	30	1.00	•03500	•14000	217A	
		•	Э <u>с</u>	•	• 20000	900	1	
23		•	30	•	• 22000	3 40560	17	
	CONNECTORS RF	•	30	•	00000	•64000	-	
F-	CONVECTOR & PINS	•	30	•	.18200	1.09200	17	
8	. GUARTZ	•	<u>ع</u>	1.00	•02000	040	1	
4	SILICON, 0-1	•	30	•	• 25500	-	17	
23	E, SILICON,	•	30	•	• 43000	4.64400	1	
		•	30	•	•10000	• 20000	17	
24	FIXED	•	30	10.00	00400	• 00400	17	
	RESISTOR, FIXED	•	30	• 30	.17000	2.60100	17	
SS	RESISTOR, NON	•	30	•	39 • 30000	23.58002	17	
	RESISTOR, MM VAR. LEAD SCREW ACT.	•	30	•	00960•	3045600	2	
		•	9 6	•	•30000	• 30000	17	
	RANSFORMER		30	•	•22000	4	•	
	TRANSFORMER, POWER	•	3C	ò	• 22000	2.20000	7	
23	TRANSISTOR, SILICON APA, 0-1	•	9 6	•	• 25500	62	17	
23	TRANSISTOR, SILIC	•	30	8.00	•51000	4.89603	17	
	ZENER DIBDE, 0-1 WATT	90	3 0	•	.77000	4 • 62303	-	
	THERMOSTAT	•	30	•	• 20000		17	

TOTAL FAILURE RATE EQUALS 73.6

73.66083 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 13575.7344 HBURS

-

50.00000 FAILURES PER MILLIAN HOURS DESIGN FAILURE RATE GOAL

F-85

		NUTES	
		F.R. SBURCE	217A 217A
MBDEL LAPOS SYSTEM		FAILURES PER MILLION ARS.	• 16003 2•18400
אפסבר ראף	50• C	BASIC FAILJRE RATE	• 0+000 • 18200
LES		FACTOR	6.00
BUTSIDE CABLES	TEMP	STRESS IN A STRESS IN A STREET	0 e e
MBOULE BU		3	2.0
PRBJECT 3995-113	UATE AP4 20,171	COMPONENT DESCRIPTION	SN
989	LAU	COMPONENT	CONNECTOR, RF CONNECTOR, 8 PINS

2.34400 FAILURES PER MILLION HOURS 426621.3125 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FAILURE RATE EQUALS

Budgen B

PREJECT 3995-113

50° C TEMP

TOTAL OF ALL MOUULES

DATE APR 20,171

1051+01831 FAILURES PER MILLIBN HOURS 951.4580 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FALLURE RATE EQUALS

APPENDIX F-4.3

RELIABILITY TEST CONDITION

RELIABILITY PREDICTION DATA SHEETS

POSITIONING SET AN/PSQ-101

ENVIRONMENT: GROUND

TEMPERATURE: +25°C

STRESS LEVELS: 30% (ASSUMED)

9.0

YODEL ALT UNIT MODULE POWER CONVERTER PRBJECT 3995-113

25. C

DATE APR 20,171

	9	STRESS IN	¥ 1	3A51C	FAILURES PER	F . R .	
COMPONENT DESCRIPTION		PERCENT	FACTOR	FAILURE KATE	AILLIDY AKS.	SOURCE	MOTES
CAPACITUM, CEN, CK	3.6	30.	1.33	•03512	.01537	217A	
	9.0		1.30	.11000	C^660·	217A	
CAPACITOR, FOIL TANT, CL	0°0		1.00	.06600	•13260	217A	
	8.0	30	1.00	•22000	1.76060	2174	
DIBDE, SILICEN, 0-1 MATT	8.0	၁၉	1.50	•25500	3.06000	2174	
DIBDE, SILICON, 1-50 WATT	1:0	30	1.00	00064.	· \$3000	2174	
FILTER, FEED THRU	0.6	30	1.00	•01000	00000	2174	
FIXED	8.0	30	00.9	•00350	•01660	2174	
RESISTOR, FIXED METAL FILM	4.0	30	• 03	.12000	.014+0	217A	
TRANSFORMER, KF	1.0	30	1.50	• 22000	•33000	217A	
TRANSISTUR, SILICON APA, 0-1 WATT	1.0	30	1.50	• 25500	• 38250	217A	
TRANSISTOR, SILICON NPW, 1-50 WATT	1.0	30	1.00	.51000	• 51000	217A	
TRANSISTOR, SILICEN PNP, 0-1 WATT	2.0	30	1.50	•67000	2.01000	217A	
ZENER DIBDE, 0+1 WATT	1.0	30	1.00	•77000	•77000	217A	
CONNECTOR, 8 PINS	1.0	30	1.10	•18200	•20050	2174	

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F-89

9.82027 FAILURES PER MILLION HOURS ** .00000 FAILURES PER MILLIUN HOURS MEAN TIME BETWEEN FAILURES EQUALS 101830-1875 HBURS TOTAL FAILURE RATE EQUALS DESIGN FAILURE RATE GOAL

MOTOROLA, INC. FAILURE RATE DETERMINATION

PR9JECT 3995-113 MODULE	1.1	RF/1F		MODEL A/T	トロスコ トハイ		
DATE APH 20.171		TEMP	Р 25.	.			
		STRESS IN	~	BASIC	FAILURES PER	F . R	
COMPONENT DESCRIPTION	710	PERCENT	FACTBR	FAILURE RATE	ā.	SBURCE	NOTES
APACITUM, CEM, CK	15.0	30	1.30	.00512	•07667	217A	
APACITOR, MICA, CM	2.0	30	1.40	• 00052	• 60145	217A	
:01L, RF	1.0	30	1.00	• 22000	• 22000	217A	
CONNECTOR, RF	3.5	30	1.10	• 04000	•15400	217A	
CONNECTOR, 15 PINS	• 5	30	1.10	•34300	• 18865	217A	
INTEGRATED CINCUIT, LINEAR	5.0	3 0	1.00	.40000	2.00000	217A	
RELAY, HALF CRYSTAL CAY	1.0	30	2.50	•00310	• 00775	2174	
RESISTOR, FIXED CARBON COMPOSITION	19.0	30	00.9	•00320	• 03990	217A	
RESISTORS NON-AM VAR. L. S. ACT.	1.0	ى ن	•10	33.42499	• 33425	217A	-1
DIBDE, HOT CARRIER	0.4	30	1.50	•65000	3.90000	217A	
TANSFORMER, RF	2.0	3C	1.50	• 22000	• 66000	217A	
CAPACITOR, VAR AIR, CT	2.0	30	1.00	• 02250	•04200	217A	

7.62787 FAILURES PER MILLION HOURS 19.00000 FAILURES PER MILLION HOURS MEAN TIME BETWEEN FAILURES EGUALS 131098-1875 HBURS TOTAL FALLURE RATE EQUALS DESIGN FAILURE RATE GOAL

NOTE1: FACTOR OF 0.1 APPLIED TO FAILURE RATE DUE TO NO FIELD ADJUSTMENTS

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MADEL ALT UNIT 25. C MBDULE PBWER AMPLIFIER TEMP PRBJECT 3995-113 DATE AP4 20,171

COMPONENT DESCRIPTION	QTY	STRESS IN PERCENT	FACTOR	BASIC FAILURE RATE	FAILURES PER MILLIBN HRS.	F.R. SBURCE	NOTES
	61.0		1.00	• 00512	•31262	217A	
	24.0		1.00	• 22000	5.28000	217A	
	1.5	30	1.10	000000	00990	217A	
DIBDE, HOT CARRIER	3.0		1.50	•65000	2.92500	217A	
	8.0		1.50	• 25500	3.06000	217A	
7	33.0		6 •00	•03320	• 06930	217A	
	10.0		1.50	• 22000	3•30000	217A	
	0.6		1.50	•67000	9.04500	217A	
LPAT DELL	1.0	30	1.50	• 25500	• 38250	217A	
1-50 WATT	9.0	ع	1.00	.51000	4 • 59000	217A	
	٠ •	30	1.10	1.22500	•67375	217A	

29.70415 FAILURES PER MILLION HOURS TOTAL FAILURE RATE EQUALS

MEAN TIME BETWEEN FAILURES EQUALS 33665.3320 HBURS

95.00000 FAILURES PER MILLION HOURS DESIGN FAILURE RATE GOAL

MSDEL 4/T UNIT	25• C
18DULE XMTR MBDULATOR	TEMP
PRBJECT 3995-113	DATE AP4 20,171

SBURCE NOTES	17A	217A	17A	17A	17A	17A	17A	17A	17A	17A	17A	
MILLIBN HRS. SBL		• 02200										
FAILURE MATE	•00512	.11000	• 22000	•65000	• 25500	00004.	•00310	•00320	• 22000	• 25500	•77000	
FACTBR	1.00	1.00	1.00	1.50	1.50	1.00	2.50	6.30	1.50	1.50	1.00	
GTY PERCENT		2.0 36										
COMPONENT DESCRIPTION	CAPACITOR, CEM, CK	CAPACITOK, SLD TANT, CSR	COIL, RF	DIBDE, HOT CARRIER	DIBDE, SILICBN, 0-1 AATT	INTEGRATED CIRCUIT, LINEAR	RELAY, HALF CRYSTAL CAN	S4 RESISTBR, FIXED CARBON CUMPOSITION			S ZENER DIBDE, 0-1 MATT	

HBURS		HOURS
MILLIBN	(A)	HILLION
PER	HBUR	PER
18.91898 FAILURES PER MILLION HOURS	52856.9805	52.00000 FAILURES PER MILLION HOURS
18.	EQUALS	52.0
TOTAL FAILURE RATE EQUALS	MEAN TIME BETWEEN FAILURES EQUALS 52856.9805 HBURS	DESIGN FAILURE RATE GBAL

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Name of Street, or other Persons and Street,

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AP 20, 171
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		STRESS IN	Y	BASIC	FAILURES PER	, A.	
COMPONENT DESCRIPTION	OTY	PERCENT	FACT93	FAILURE RAFE	MILLIBY HRS.	SOURCE	NUTES
CAPACITOR, CER, CK	2230		1.50	51600.	575110	21.74	
					21144	2173	
CAPACITORS ALCAS CE	16.0		1 • +0	• 00052	•01159	217A	
COIL, RF	8.0		1.00	• 22000	1.76000	217A	
DIODE, HOT CARRIER	12.0		1 • 50	•65000	11.7000	2174	
DIBDE, SILICOV, 0-1 AATT	5.0	30	1.50	• 25500	1.91250	217A	
INTEGRATED CINCUIT, LINEAR	2.0		1.00	00000	.80000	2174	
S+ RESISTOR, FIXED CARBON COMPOSITION	57.0		9	• 00350	.11970	2174	
ICON	0.9		1.50	• 25500	2.29500	2174	
TRANSISTOR, SILICEN PNP. 0-1 MATT	0		1.50	•67000	2.01000	217A	
C TRANSFORMER, AF	0.4		1.50	• 22000	1.32000	217A	
RESISTOR, VARIABLE, 10-TJRN	1.0		1.00	1.01500	1.01500	SM-188	

HBURS	
MILLIBN	
PER	
FAILURES	
23.05650	
EGUALS	
RATE	
FAILURE	
TOTAL	

MEAN TIME BETWEEN FAILURES EQUALS +3371-7109 HOURS

DESIGN FAILURE RATE GOAL

66.00000 FAILURES PER MILLION HOURS

HODEL AZT UNIT	
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CT 3995-113	DATE APY 20, 171
PRBJECT	DATE

COMPONENT DESCRIPTION	VT0	STRESS IN	IN K FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.K. SBURCE	AUTES
CAPACITUM, CER, CK	22.0		1.00	•00512	•11275	217A	
CAPACITOR, MICA, CM	16.0	30	1.40	•00052	•01159	217A	
COIL, RF	8.0	30	1.00	• 22000	1.76000	217A	
DIODE, HOT CARRIER	12.0	3C	10	•65000	11 • 70000	217A	
DIBDE, SILICON, 0-1 MATT	5.0	30	1.50	• 25500	1.91250	217A	
INTEGRATED CINCUIT, LINEAR	2.0	30	1.00	00000	60000	217A	
S+ RESISTOR, FIXED CARBON COMPOSITION	57.0	30	6.00	•00320	•11970	217A	
TRANSISTUR, SILICON NPN, 0-1	0.9	30	1.50	• 25500	2.29500	217A	
TRANSISTUR, SILICON PNP. 0-1 MATT	2.0	30	1.50	•67000	2.01000	-	
TRANSFORMER, KF	0.,	30	1.50	•22000	1 • 32000	217A	
-	1.0	20	1.00	1.05500	1.05500	SM-188	
CONNECTOR, RF	3.0	30	1.10	00040•	•13200	-	
CONNECTOR, 15 PINS	• 0	30	1.10	•34300	•18865	2174	

23.41713 FAILURES PER MILLION HOURS		66.00000 FAILURES PER MILLION HOURS
S PER	HBURS	PER
3 FAILURE	42703.7813 HBURS	FAILURES
23.4171	EQUALS +	000000 • 99
TOTAL FAILURE RATE EQUALS	MEAN TIME BETWEEN FAILURES EQUALS	DESIGN FAILURE RATE GOAL
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FAILURE RATE DETERMINATION MBTBRBLA, INC.

CARRIER IG/VCB MODULE PRBJECT 3995-113

MADEL A/T UNIT

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TEMP

AP 20,171 DATE

F.R. SBURCE FAILURES PER MILLIBN HRS. .04503 BASIC FAILURE RAIE FACTOR STRESS IN PERCENT COMPONENT DESCRIPTION VAR AIR, CT

217A 217A • 02250 .36900 7 • 60000 1.32000 • 13200 1.91250 1 • 20000 .16820 3.83400 1.91250 2.31000 3.90000 •66000 00090 .01100 .02475 .01014 ·18865 •09720 34300 •02475 00512 00000 00052 22000 25500 00004. 40000 03350 .12000 .07100 .25500 .77000 65000 •22000 02020 .03275 02550 000 1.50 04. 000 1.10 1.10 1.50 00.1 1.00 9.00 1.50 1.50 00 - 1 00.1 000 •03 1.00 18.00 27.0 5.0 5.0 72.0 14.0 0.9 3.0 5.0 3.0 19.0 80.0 3.0 3.0 4.0 1.0 2.0 RESISTOR, FIXED CARBON COMPOSITION RESISTOR, WW VAR. LEAD SCREW ACT. TRANSISTOR, SILICON NPV. 0+1 WATT TRANSISTOR, SILICON NPN. 0+1 INTEGRATED CIRCUIT, DIGITAL INTEGRATED CIRCUIT, LINEAR RESISTOR, FIXED METAL FILM RESISTOR, FIXED HETAL FILM DIBDE, SILICON, 0-1 HATT CAPACITOR, T C CER, CC CAPACITOR, VAR GLASS, PC CAPACITOR, VAR CER, CV ZENER DIODE, 0-1 MATT MICA, CM CER, CK CONNECTOR, 15 PINS DIBDE, HOT CARRIER TRANSFORMER, RF CRYSTAL, GUARTZ CONNECTOR, RF CAPACITORS CAPACITURA CAPACITOR COIL, AF F-95

25.7724 FAILURES PER MILLION HOURS TOTAL FAILURE RATE EQUALS

38793.9141 HOURS MEAN TIME BETWEEN FAILURES EQUALS

DESIGN FAILURE RATE GOAL

54.00000 FAILURES PER MILLIBN HOURS

MODEL A/T UNIT	
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CBDE DETECTOR	TEMP
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PR9JECT 3995-113	DATE APH 20, 171

	S	TRESS IN		BASIC	FAILURES PER	F.R.	
COMPONENT DESCRIPTION	710	UTY PERCENT		FAILURE MATE	MILLION HRS.	SOURCE	MOTES
CAPACITUM, CEM, CK	0.94	30	1.30	-00512	• 23575	217A	
CAPACITON, MICA, CM	0.4	30	1.40	•00052	.00293	217A	
CONNECTOR 15 PINS	•	30	1.10	•34300	•18865	2174	
~	7.0	30	1.50	.25500	2.67750	2174	
	3.0	30	1.00	00000	1.20003	2174	
INTEGRATED CINCUIT, LIVEAR	19.0	30	1.30	00004.	7-60000	2174	
RESISTOR, FIXED NETAL FILM	28.0	30	• 23	.12000	-10080	2174	
RESISTOR, WH VAR. LEAD SCHEW ACT.	1.0	30	18.00	.07100	1.27800	RADC	
TRANSISTUR, SILICON JPAN 0-1 MATT	1.0	ЭĊ	1.50	•25500	•38253	2174	

13-66609 FAILURES PER MILLIBN MOURS LS 73173-7500 HOURS	TOURS
ER MILLION JRS	-
SAS	ILLION
4	PER M
09 FAILURES PER 73173.7500 HBURS	16.00000 FAILURES PER MILLION HOURS
13.66609 EQUALS 7:	16.00000
GUALS	GOAL
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TOTAL FAILURE RATE EQUALS 13. HEAN TIME BETWEEN FAILURES EQUALS	DESIGN FAILURE RATE GOAL

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		STRESS IN	¥	BASIC		F . K .	
COMPONENT DESCRIPTION	TTC	GTY PERCENT FACTOR	FACTBR	FAILURE RATE	MILLIBY ARS.	SOURCE	MALES
CAPACITON, CEN, CK	30.0			• 00518	•15375	217A	
SA INTEGRATED CIRCUIT, DISITAL	71.0		1.00	00000	8 52000	2174	
RELAY, HALF CRYSTAL CAN	1.0		2.50	•00310	• 30775	217A	
S. RESISTOR, FIXED CARBON COMPOSITION	54.0		00.9	•00320	•11340	2174	
CAPACITOR, MICA, CM	0.9		1.40	• 00052	•00435	2174	
COIL, RF	3.0		1.00	• 22000	C0099 ·	2174	
CONNECTOR, RF	0.9		1.10	000000	• 26400	2174	
CONNECTOR, 36 PINS	• •	30	1.10	1.22500	•67375	217A	

10-39693 FAILURES PER MILLION HOURS 20.00000 FAILURES PER MILLION HOURS 96182.2500 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FAILURE RATE EQUALS DESIGN FAILURE RATE GOAL

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PRBJECT 3995-113	DATE APR 20,171
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COMPONENT DESCRIPTION	SYTO	STRESS IN A GITY PERCENT FACTOR	FACTOR	BASIC FAILURE RATE	MILLION HRS.
CONNECTOR, RF CONNECTOR, 15 PINS CONNECTOR, 15 PINS	2000 m	0000	0000	. 18200 . 34300	• 79200 • • 000 • 0 1 • 13190
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NOTES

F.R. SOURCE

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HBURS	
ILLION	
PER M	HBURS
FAILURES PER MILLION HOURS	230120.4375 HBURS
•34555	23018
*	GUALS
EGUALS	MEAN TIME BETWEEN FAILURES EQUALS
RATE EQUALS	FEN FI
ILURE	E BETH
TOTAL FAILURE	FIL N
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MODEL AZT UNIT	
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PROJECT 3995-113	DATE APR 20,171
PROJECT	SATE A

			STRESS IN	Y	BASIC	FAILURES PER	72.	
	COMPONENT DESCRIPTION	YTE	PERCENT	FACTOR	FAILURE MATE	MILLION HRS.	SOURCE	NOTES
	CAPACITOR, VAR AIR, CT	0	30	1.00	05660	0,666.	47.50	
			•					
	CAPACITUM, CEK, CK	36.0	30	1.00	•00512	• 18450	2177	
	CAPACITUR, MICA, CM	10.0	30	1.40	• 00052	•00724	217A	
		0.9	30	1.00	• 22000	1.32000	217A	
	CONNECTOR, RF	3.0	30	1.10	000000	•13200	217A	
	CONNECTOR, 15 PINS	ເດ	30°	1.10	•34300	• 18865	2174	
	DIODE, SILICON, 0-1 MATT	50	30	1.50	• 25500	•76500	217A	
	INTEGRATED CIRCUIT, LINEAR	12.0	3C	1.00	00004.	4 • 80000	217A	
24		48.0	30	00.9	•00350	.10060	217A	
		13.0	30	•03	• 12000	.34683	217A	
F-		1.0	30	18.00	•07100	1.27800	RADC	
99	TRANSFORMER, RF	0.9	30	1.50	• 22000	1.98000	2174	
•		2.0	30	1.50	•25500	•76500	217A	
	ZENER DIBDE, 0-1 WATT	1.0	30	1.00	•77000	•77000	217A	
	DIODE, HOT CARRIER	•	30	1.50	•65000	3.90000	217A	
	CAPACITOR, T C CER, CC	0.4	30	1.00	• 00275	•01100	217A	
	CRYSTAL, GUARTZ	2.0	30	1.00	•05000	000+0•	217A	

16.31146 FAILURES PER MILLION HOURS 36.00000 FAILURES PER MILLION HOURS MEAN TIME BETWEEN FAILURES EQUALS 61306.5781 HOURS TOTAL FAILURE RATE EQUALS DESIGN FAILUNE RATE GOAL

MADEL A/T UNIT CLOCK PHASE CONTROL TEMP **BUDGEN** PRBJECT 3995-113 DATE APR 20,171

COMPONENT DESCRIPTION	VT0	STRESS IN	FACT9R	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SBURCE	NOTES
CAPACITON, CEN, CK	38.0	30	1.00	• 00512	•19475	21.7A	
CAPACITUR, MICA, CM	4.0	၁ ၉	1 - 40	- 00052	• 00290	217A	
COIL, RF	5.0	30	1.00	• 22000	1 • 10000	217A	
DIBDE, SILICBN, 0-1 MATT	1.0	30	1.50	• 25500	• 38250	2174	
INTEGRATED CINCUIT, DISITAL	4.0	30	1.00	00004.	1 • 60000	217A	
INTEGRATED CINCUIT, LIVEAR	12.0	30	1.00	00004•	4 • 80000	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION	28.0	30	6.00	•00320	• 05880	217A	
RESISTOR, FIXED METAL FILM	10.0	30	•03	•12000	•03600	217A	
THESISTOR, WW VAR. LEAD SCREW ACT.	1.0	30	18.00	.07100	1.27800	RADC	
1 TAANSFORMER, KF	2.0	30	1.50	• 22000	1 • 65000	217A	
O TRANSISTOR, SILICON YPN, 0-1 AATT	1.0	30	1.50	• 25500	• 38250	217A	
DIGOE, HOT CARRIER	4.0	30	1.50	• 65000	3 • 90000	217A	
CAPACITOR, T C CER, CC	8.0	30	1.00	• 00275	• 02200	217A	
CRYSTAL, QUARTZ	*	30	1.00	•05000	• 08000	2174	

15.48744 FAILURES PER MILLION HOURS 30.00000 FAILURES PER MILLION HOURS 64568.4453 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FAILURE RATE EQUALS DESIGN FAILURE RATE GBAL

MOTOREAL INC. FAILURE RATE DETERMINATION

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MODEL POSITIONING SET	
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PH0JECT 3995-113	DATE AP4 200'71

		STRESS IN	Y	BASIC	FAILURES PER	F. K.	
COMPONENT DESCRIPTION	710	PERCENT	FACTBR	FAILJRE RATE	MILLION ARS.	SOURCE	NOTES
CAPACITOW, CER, CK	68.0		1.00	-03512	. 3480 	21.7A	
CAPACITUM, T C CEM, CC	2.0		1.00	.00275	• 20553	217A	
2	20.0		1.40	.03052	6+410.	2174	
CAPACITON, SLD TANT, CSR	5.0		1.00	•11000	•05500	2174	
COIL, AUDIO	1.0		1.50	• 20000	• 30000	217A	
C91L, AF	3.0		1.00	• 22000	·66000	217A	
S'S INTEGRATED CIRCUIT, DIGITAL	41.0	30	1.00	00004.	4.92000	2174	
INTEGRATED CINCUIT, LINEAR	12.0		1.00	0000	4.80000	2174	
SA RESISTOR, FIXED CARBON COMPOSITION	0.40		6.00	.00350	.11343	217A	
RESISTORY FIXED METAL FILM	3.0		•03	.12000	.02853	217A	
TRANSFORMER, RF	2.0		1.50	.22000	•66000	2174	
TRANSISTOR, SILICON APA, 0-1 HATT	1.0		1.50	•25500	•38250	217A	

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DATE APR 20, 171

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	COMPONENT DESCRIPTION	OTY	PERCENT	FACTOR	FAILURE HATE	MILLION HRS.	SBURCE	NOTES
	CAPACITOM, SLU TANT, CSR	0.9		1.00	.11000	• 06603	217A	
	CAPACITOR, FOIL TANT, CL	2.0	30	1.00	00990	• 13200	217A	
	CBIL, AUDIB	1.0		1.50	• 20000	• 30000	217A	
	DIBDE, SILICON, U-1 WATT	15.0		1.50	• 25500	5 • 73750	217A	
		1.0		2.50	•00310	• 00775	217A	
Š	RESISTOR, FIXED CARBON COMPOSITION	19.0		00.9	•00350	.03990	217A	
2		8.0		• 03	•12000	+0000	217A	
	TAANSFORMER, POWER	1.0		1.50	• 22000	• 33000	217A	
F		4.0		1.50	.25500	1.53000	2174	
- 1	, TRANSISTOR, SILICON VPV, 1-50 HATT	1.0		1.00	•51000	•51000	217A	
02		3.0	30	1.50	•67000	3.01500	217A	
!	•	3.0	3 <u>0</u>	1.00	•77000	2.31000	217A	
	CAPACITOR, CER, CK	3.0	30	1.00	•00512	•01537	217A	
	CONNECTOR, 15 PINS	S.	90 8	1.10	•34300	• 18865	•	

14-18224 FAILURES PER MILLION HOURS 46.00000 FAILURES PER MILLIAN HOURS 70510-6875 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FAILURE RATE EQUALS DESIGN FAILURE RATE GOAL

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	4	STRESS IN A	× 0	BASIC	FAILURES PER	T	
CONTRACTOR CENTRALION	3	1 E X C E V I	1 AC 0 K	PAILURE TAIE	TILLION HAS.	30086	NOTES
CAPACITON, CER, CK	15.0		1.00	•00512	• 37687	217A	
CONNECTOR, 36 PINS	1.0		1.10	1.22500	1.34750	2174	
S3 INTEGRATED CIRCUIT, DISITAL	0.44	30	1.00	· 40000	5.28000	217A	
S. RESISTOR. FIXED CARBON COMPOSITION	2.0		00.9	• 00320	•01050	217A	

	HBURS
10	ILLIUN
HBURS	PER
1923 • 4375	13.00000 FAILURES PER MILLION HOURS
148	00000
EGJALS	13•(
ILURES	GBAL
EEN FL	DESIGN FAILURE RATE GOAL
BETW	ILURE
3 11 V	IGN FA
HEAP	DES
	MEAN TIME BETWEEN FAILURES EGUALS 148923.4375 HOURS

	NOTES	
	F.R. SBURCE	217A 217A 217A
MODEL POSITIONING SET	FAILURES PER MILLION HRS.	.082U3 1.34750 5.64000 .03780
RL 46DEL 26S 25. C	BASIC FAILURE RAIE	.00512 1.22500 .40000
PUT CTRL	FACTOR	6.000
DPU MSG BUTPUT CTRL	STRESS IN K PERCENT FACTOR	3333 8 8 8 8
	S	16.0 47.0 18.0
PRBJECT 3995-113 MBDJLE DATE APR 20,171	COMPONENT DESCRIPTION	CAPACITUR, CER, CK CONNECTOR, 36 PINS S3 INTEGRATED CIRCUIT, DIGITAL S4 RESISTOR, FIXED CARBON COMPOSITION

est o

7.10728 FAILURES PER MILLION HOURS

13.00000 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 140700.7500 HOURS

DESIGN FAILURE RATE GOAL

TOTAL FAILUNE RATE EQUALS

MOTORBALA, INC. FAILURE RATE DETERMINATION

SET	
MODEL POSITIONING SET	
MODEL	
-	25• C
10	2
DPU DATA ASMBLR & ST	LEMP
DATA	
DPU	
MODULE	
PR6JECT 3995-113	DATE APR 20,171
368	2
ECT	*
PRBJ	DATE

	217A	•01260	• 00320	00.9	30	0.9	S. RESISTOR, FIXED CARBON COMPOSITION	-
	217A	5.52000	00000	1.00	ع ص	0.94	S. INTEGRATED CINCUIT, DIGITAL	
	217A	1.34750	1.22500	1.10	30	1.0	CONNECTOR, 36 PINS	
	217A	-07667	•00512	1.00	30	15.0	CAPACITOR, CER, CK	
NUTES	SOURCE	MILLION HRS.	BASIC FAILURE RATE	FACTBR	OTY PERCENT FACTOR	S Y TO	COMPONENT DESCRIPTION	-

13.00000 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 143741.1250 HOURS

DESIGN FAILURE RATE GBAL

FAILURE RATE DETERMINATION MOTORBLA, INC.

DPU COMMAND DECODER MODOLE PRBJECT 3995-113

MADEL POSITIONING SET

U 25.

TEMP

AP4 20,171 DATE

F.K. SOURCE 2174 2174 2174 2174 FAILURES PER MILLIBN MRS. .01100 1.34750 5.28000 •07175 BASIC FAILURE RATE .00512 .40000 •00350 .11000 STRESS IN K GTY PERCENT FACTOR 1000 1 • 10 1.00 **၁၁၁၁၁** INTEGRATED CINCUIT, DISITAL RESISTBR, FIXED CARBON COMPOSITION CAPACITOR, SLD TANT, CSK COMPONENT DESCRIPTION CAPACITUM, CEM, CK CONNECTUM, 36 PINS

NOTES

6./5223 FAILURES PER MILLION HOURS TOTAL FAILURE RATE EQUALS

148099.2500 HBURS MEAN TIME BETWEEN FATLURES EQUALS 13.00000 FAILURES PER MILLION HOURS DESIGN FAILURE RATE GBAL

50

MBTBRBLA, INC. FAILURE RATE DETERMINATIBN

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EL POSITIONING SET	
MEDEL	
	25. C
PU MEMBRY	TEMP
MBDULE	
PRBJECT 3995-113	DATE APK 20, 171

	COMPENENT DESCRIPTION	₽¥±0	STRESS IN	FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION ARS.	F.R. SBURCE	NUTES
	CAPACITBM, GLASS, CY	5.0	э Э	1.00	.00773	• 03863	217A	
	CAPACITUR, CER, CK	34.0	30	1.00	•00512	+17425	217A	
-	CAPACITER, SLD TANT, CSR	7.0	3 <u>0</u>	1.00	•11000	• 07700	217A	
	CONVECTOR, 36 PINS	\$	30	1.10	1.22500	•67375	2174	
S	I INTEGRATED CINCUIT, DISITAL	59.0	30	1.00	00004.	7.08000	2174	
s	S& RESISTOR, FIXED CARBON COMPOSITION	18.0	30	00.9	• 00320	•03780	2174	
s	RESISTOR, FIXED METAL FILM	*	30	• 03	•12000	+0001+	2174	
	INTEGRATED CINCUIT, LINEAR	8•0	30	1.00	00004.	3.20000	217A	

11-28156 FAILURES PER MILLION HOURS TOTAL FAILURE RATE EQUALS

MEAN TIME BETWEEN FAILURES EQUALS 88640.2500 HOURS

22.00000 FAILURES PER MILLION HOURS DESIGN FAILURE RATE GOAL

FALLURE RATE DETERMINATION MBTSRBLA, INC.

MADEL POSITIONING SET CABLE MARNESS-JPU MODULE PRBJECT 3995-113

FAILURES PER MILLION HRS. .08800 .18865 9.43251 BASIC FAILURE MATE .04030 .34300 1.22500 Ų 25. FACTOR 1.10 TEMP STRESS IN 3000 OTY AP4 20, 171 COMPONENT DESCRIPTION CONNECTOR, RF CONNECTOR, 15 PINS CONNECTOR, 36 PINS CONNECTOR, 20 PINS DATE

NUTES

F.R. SOURCE

2174

2174

•26730

.48600

1.10

9.97645 FAILURES PER MILLIBN HBURS 100236.0000 HBJRS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FAILURE RATE EGUALS

27.00000 FAILURES PER MILLION HOURS DESIGN FAILURE RATE GOAL

	V6IT
INC	RHINA
ROLA,	DETE
MOTOR	RATE
-	FAILURE

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LABILIBAL .	
4 906	
	75. C
-OP:U	25.
PANEL-JPU	T T
CONTROL	
Medule	
3995-113	171
995	00
	APR 20.171
RBJECT	
PR	DATE

COMPONENT DESCRIPTION	710	STRESS IN A GIT PERCENT FACTOR	FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SBURCE	NOTES
COIL, RF	9.0		1.30	• 22000	1.32303	217A	
FUSE	1.0		1.00	•10000	•10000	217A	
SWITCH, TOGGLE BR PUSHBUTTON	46.0		1.00	•25000	11 • 50000	217A	
CAPACITUR, CER, CK	12.0		1.00	•00512	.06153	217A	
CONNECTOR, 36 PINS	1.0		1.10	1.22500	1.34750	217A	
INTEGRATED CIRCUIT, DIGITAL	0.99	30	1.00	00004.	26 • 39999	2174	
S+ RESISTOR, FIXED CARBON COMPOSITION	162.0		00.9	•00320	•34050	2174	

41.06918 FAILURES PER MILLIBN HBURS	HOURS	PER MILLION HOURS
41.06918 FAILURES	JUALS 24349.1562 HBURS	172.00000 FAILURES PER MILLIUN HOURS
TOTAL FAILURE RATE EQUALS	MEAN TIME BETWEEN FAILURES EQUALS	DESIGN FAILURE RATE GOAL

MOTOROLA, INC. FAILURE RATE DETERMINATION

POSITIONING SET	
1306k	
	5. C
DATA DISPLY UNIT	TEMP
MBJULE	
PR6JECT 3995+113	DATE MAY 34,171

		S	TRESS IN	¥	BASIC	FAILURES PER	F. R.	
	COMPONENT DESCRIPTION	ATC	PERCENT	FACTOR	FAILURE RATE	MILLIBY HAS.	SOURCE	VOTES
	CAPACITOR, CER, CK	20.0	30	1.00	•00512	•10250	217A	
	COIL, RF	2.0	30	1.00	•22000	00044.	2174	
	CONNECTOR, 10 PINS	ņ	30	1.10	• 22200	.12210	2174	
	FUSE	8.0	30	1.00	•10000	• 20000	2174	
	INTEGRATED CIRCUIT, DISITAL	31.0	30	1.00	00000	12.40000	2174	
Š		5.0	30	00.9	•00320	•01050	2174	
	RESISTOR, VARIABLE CARBON COMP.	1.0	30	10.00	•10000	1.00000	2174	
	SAITCH, TOGGLE OR PUSHBUTTON	2.0	30	1.00	• 25000	.50000	217A	
F	TRANSISTOR, SILICON YPY, 1-50 WATT	2.0	30	1.00	.51000	1.02000	217A	
-1	CAPACITOR, SLO TANT, CSR	••	30	1.00	•11000	004400	2174	
10	SILICON, 0-1	9.0	90	1.50	•25500	2.29500	217A	
)	RELAY, HALF CRYSTAL CAN	1.0	30	2.50	•00310	•00775	217A	
	INDICATOR.HP5082-7000	20.0	30	1.00	.80580	16-11600	SM-188	

34.25783 FAILURES PER MILLION HOURS	29190.4062 HBURS	127-00000 FAILURES PER MILLION HOURS
34.2	EQUALS	127.000
TOTAL FAILURE RATE EQUALS	MEAN TIME BETWEEN FAILURES EQUALS	DESIGN FAILURE RATE GOAL

METBRBLA, INC. FAILURE RATE DETERMINATION

PROJECT 3995-113 MODULE DOU PWR SUP

MODEL POSITIONING SET

DATE APH 20, '71

TEMP 25. C

COMPONENT DESCRIPTION	Q17	PERCENT	FACT9R	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	YUTES
CAPACITUM, SLU TANT, CSR	9.6	30	1 • 00	•11000	0.990•	217A	
CAPACITER, FBIL TANT, CL	2.0	3C	1.00	• 06600	•13200	217A	
COIL, AUDIO	1.0	30	1.50	.20000	• 30000	217A	
	15.0	30		• 25500	5 • 73750	-	
	1.0	30	2.50	.00310	•00775	-	
	19.0	30		•00350	• 03990	-	
RESISTOR, FIXED METAL FILM	2.0	30	• 03	•12000	400007		
TAANSFORMER, POWER	1.0	30	1.50	• 22000	• 33000	-	
TRANSISTOR, SILICEN APA, 0-1 MATT	0.4	30	1.50	.25500	1.53000		
ISTOR, SILICON APA, 1-50 WATT	1.0	3C	1.00	.51000	•51000	7	
TRANSISTUR, SILICON PNP, 0+1 WATT	3.0	30	1.50	00029.	3.01500		
ZENER DIBDE, 0-1 MATT	3.0	30	1.00	•77000	2.31000		
	3.0		1.00	•00512	•01537	217A	
CONNECTOR, 15 PINS	S.		1.10	•34300	•18865	217A	

14-18224 FAILURES PER MILLION HOURS 70510.6875 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FAILURE RATE EQUALS

DESIGN FAILURE RATE GOAL 44.

44.00000 FAILURES PER MILLIUN HOURS

MOTORDLA, INC. FAILURE RATE DETERMINATION

MBDULE CRYSTAL BSC

PRBJECT 3995-113

DATE APR 200'71

MODEL POSITIONING SET

25. C

TEMP

COMPONENT DESCRIPTION	410	STRESS IN	FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SBURCE	107
PACITBK, GLASS, CY	•	30	0	Ö	0.33	1	
CAPACITOR, CEY, Ch	•	ن	0	00	148	17	
CAPACITUR, MICA, CM	7	30	4	0	005	1	
•	•	30	C	0	920	17	
CAPACITOR, MYLAK, CT4	•	Эć	0	0	008	17	
SED TANTA	12.0	30	1.00	•11000	•13200	217A	
CAPACITOR, VAR CER, CV	•	3ú	0	02	060	17	
CBIL, AUUIS	•	ЭĊ	ເບ	20	600	17	
COIL, RF	•	<u>ვ</u> ი	Ç	22	320	17	
CONNECTOR, RF	•	<u>ာ</u>		Ç	•176	17	
CONNECTOR, 8 PINS	•	30		18	203	17	
CRYSTAL, QUARTZ	•	30		S	040	17	
SILICON, 0-1	•	30	ເບ	25	915	17	
DIBDE, SILICON, 1-90 WATT	•	30	0	E 4	290	17	
	•	30	0	10	• 200	17	
FIXED	÷	30	0	00	909	17	
FIXED METAL	•	ع ت	C	12	183	17	
A3. L	•	30	-	42	1027	17	
SISTOR, WH VAR. LEAD SCREW ACT.	•	30	0		2.556	9	
THERMISTOR	•	<u>၁</u> ၉	0	30	300	17	
	•	30	5	22	999	17	
POWER	•	30	S.	N	330	17	
SILICON YPY, 0-1	•	30	S.	255	•677	17	
ISTOR, SILICON YPY	•	30	0	51	•040	17	
•	•	9 0	·	77	540	17	
HERMOSTAT	•	30	0	C	-200	17	

26.70258 FAILURES PER MILLIBN HOURS

TOTAL FAILURE RATE EQUALS

Comment.

50.00000 FAILURES PER MILLIAN HOURS 37449.5703 HBURS A Management of MEAN TIME BETWEEN FAILURES EQUALS DESIGN FAILURE RATE GEAL

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MOTORULA, INC. FAILURE RATE DETERMINATION

		NOTES	
		F.R. SBURCE	217A 217A
MODEL LRPUS SYSTEM		FAILURES PER MILLION HRS.	•34400 1•45600
MODEL LRP	25• C	BASIC FAILURE RATE	.04000
ES		FACTOR	6.00 0.00 0.00
BUTSIDE CABLES	7 2 3 4	STRESS IN A OTY PERCENT FACTOR	1.0 3c 3c
MODULE		710	
PRBJECT 3995-113	DATE AP4 20,171	COMPONENT DESCRIPTION	RF B PINS
		COMPO	CONNECTUR, RF CONNECTUR, 8 PINS

1.80000 FAILURES PER MILLIBN HBURS 555555.7500 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FAILURE RATE EQUALS

MOTOROLA, INC. FAILURE RATE DETERMINATION

Parameter 1

PROJECT 3995-113 TOTAL OF ALL MODULES

DATE APH 200'71

TEMP 25. C

580.68921 FAILURES PER MILLIBN HBURS TOTAL FAILURE RATE EGUALS

MEAN TITE BETWEEN FAILURES EQUALS 1722.0916 HBURS

APPENDIX F-4.4

WORST CASE

RELIABILITY PREDICTION DATA SHEETS

REFERENCE POSITION SET AN/ASQ-148

ENVIRONMENT: AIRBORNE

TEMPERATURE: +71°C

STRESS LEVELS: DERATING LIMITS EXCEPT

RUBIDIUM STANDARD STRESSES

10% (ASSUMED)

MOTOROLA, INC. FAILURE RATE DETERMINATION

-

IBDEL W/T UNIT	
YBDEL	
	•
	71
POWER CONVERTER	TEMP
PewER	
MEDULE	
113	171
3995-113	APR 21,171
	APA
PRBJEC.	DATE

COMPONENT DESCRIPTION	OTY	PERCENT	FACTOR	SASIC FAILURE RATE	HILLION HRS.	SBURCE	NUTES
CAPACITUM, CER, CK	3.0	50	5.00	•02425	•36375	217A	
CAPACITONS SED TANTS CSR	9.0		1.00	•75050	•67545	217A	
CAPACITURA FOIL TANTA CL	0.0		8.00	•16750	2 • 68000	217A	
	8		8 • 60	• 22000	15.13600	217A	
DIGDE, SILICON, 0-1 AATT	8.0		3.50	• +1000	11.48000	217A	
DIODE, SILICON, 1-50 WATT	1.0		12.00	00006.	10.80000	217A	
FILTER, FEED THRU	9.0		1.00	•10940	.98460	217A	
SA RESISTOR, FIXED CARBON COMPOSITION	8.0		10.00	• 02650	•21200	217A	
RESISTOR, FIXED METAL FILM	*		• 30	.24850	.29823	217A	
	7.0		10.00	• 22000	2.20000	217A	
SILICON	1.0		8.00	• +1000	3.28000	217A	
TRANSISTOR,	1.0		8.00	•82000	6 • 5 6 0 0 0	217A	
SILICON PNP.	2.0		8.00	1.25000	20 • 00000	217A	
ZENER DIGDE, 0-1 MATT	1.0		3.00	1.25000	3.75000	217A	
CONNECTOR, 8 PINS	1.0		9.00	•18200	1.09200	217A	

79.51193 FAILURES PER MILLION HOURS 12576.7266 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FAILURE RATE EQUALS

MOTGROLA, INC. FAILURE RATE DETERMINATION

MODEL AZT UNIT	
	ں •
	71
	TEMP
4F/1F	
MBDULE	
113	171
3995-113	AP4 215'71
7	AP
PKBJECT	DATE

		STRESS IN		BASIC	FAILURES PER	F.R.	
COMPONENT DESCRIPTION	TID	GTY PERCENT	FACTOR	FAILURE RATE	MILLION HAS.	SBURCE	NATES
CAPACITURA CERA CK	15.0		5.00	0.4000	. 724.13		
				30000	6113/	A/12	
CAPACITUR, MICA, CM	2.0		15.00	•00036	-01072	217A	
COIL, RF	1.0		8.60	000000	1.89200	2174	
100000000000000000000000000000000000000)				
CONNECTOR, RV	3.5		00•	00040•	• 56000	217A	
CONNECTOR, 15 PINS	ů.		00.9	.34300	1.02903	2174	
INTEGRATED CIRCUIT, LIVEAR	5.0		1.00	00004	0,000.9	21.74	
						U / T 4	
RELAY, HALF CRYSTAL CAN	1.0		50.00	.00310	•15500	217A	
SA RESISTORA FIXED CARBON COMPOSITION	19.0		10.00	•02650	• 50350	217A	
SA RESISTORS NON-NE VAR. L. S. ACT.	1.0		2.00	49.12999	9 8 8 2 6 0 3	217A	•
DIBDE, HOT CARRIER	0.4	50	3.50	1.03000	14.42000	P174	•
TRANSFORMER, RF	2.0		10.00	00000	00000	24.74	
						() 1	
A CAPACITORS AAR AIRS CI	0.0		1.00	•24700	00464	217A	

27769.0547 HBURS NOTE1: FACTOR OF 0.1 APPLIED TO FAILURE RATE DUE TO NO FIELD ADJUSTMENTS MEAN TIME BETWEEN FAILURES EQUALS

36-01131 FAILURES PER MILLION MOURS

TOTAL FAILURE RATE EQUALS

MOTORDIA, INC. FAILURE RATE DETERMINATION

PRBJECT 3995-113

MODULE POWER AMPLIFIER

YADEL 4/T UNIT

NUTES

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To a constant

-

DATE APR 12,171

71. C TEMP

	COMPONENT DESCRIPTION	GTY	STRESS IN GIY PERCENT	FACTBR	SASIC FAILURE RAIE	FAILURES PER MILLION HRS.	F.A. SBURCE	
	CAPACITOR, CER, CK	61.0		00 • €	• 51038	3 • 350 42	217A	
	Call, RF	24.0	30	8.50	• 22000	45.40800	217k	
	CONVECTOR, RF	6.0		4.00	000000	.96000	217A	
	DISJE, HOT CARRIER	3.0		3.50	•65000	6 - 82500	217A	
	DISDE, SILICON, 0-1 WATT	8.0		3.50	·25530	7.14000	217A	
Š	RESISTOR, FIXED CARBON COMPOSITION	33.0		10.00	•01193	•39353	217A.	
	TZANSFORMER, KF	10.0		10.00	• 22000	22.00000	217A	
	TAANSISTUR, FIELD EFFECT	0.0		8.30	•67030	48.23999	217A	
	TAANSISTUR, SILICON NPV, 0-1 WATT	1.0		00 • R	• 25500	2.040.5	217A	
		0.6		8.00	•51000	36.71939	217A	

173.07690 FAILURES PER MILLIBN HOURS TOTAL FAILUNE RATE EQUALS

5777.7773 HBURS MEAN TIME BETWEEN FAILURES EQUALS

97.00000 FAILURES PER MILLION HOURS DESIGN FAILURE RATE GBAL 大学 大大学 と

MOTGRGLA, INC. FAILURE RATE DETERMINATION

BDEL AZT UNIT	
5	71. C
XMTR MODULATOR	TEMP
Medule	
PR6JECT 3995-113	DATE AP4 21, 171

		STRESS IN		BASIC	FAILURES PER	¥.	
COMPONENT DESCRIPTION	QTY	PERCENT	FACTBR	FAILURE RATE	MILLIBN HRS.	SOURCE	NON
CAPACITUR, CER, CK	9.6		5•00	99690	2000	47.50	
						C / T J	
CAPACITER, SLU IANI, CSR	2.0		1.00	• 75050	•15010	217A	
COIL, RF	2.0		8 • 60	• 22000	3.78400	217A	
DIGDE, HOT CARRIER	8.0		3.50	1.03000	28 8 8 3 9 3	2174	
DIBDE, SILICBN, 0-1 MATT	10.0	50	3.50	0.014.	14.35000	217A	
INTEGRATED CINCUIT, LIVEAN	2.0		1.00	00004.	680063	2174	
RELAY, HALF CHYSTAL CAN	3.0		50.00	00310	00004.	17.0	
S. RESISTOR, FIXED CARBON COMPOSITION	30.0		10.00	07650	2000 ·	217	
TALKSFRENG KF	0.44		0000			· · · · · · · · · · · · · · · · · · ·	
F			70.04	occur.	000000	C1/A	
	10.0		8.00	+ 41000	32.79999	217A	
S ZENER DIBBES 0-1 WATT	1.0		3.00	1.25000	3.75000	217A	

TES

94.82246 FAILURES PER MILLION HOURS TOTAL FALLURE RATE EQUALS

MEAN TIME BETNEEN FAILURES EQUALS 10545.0234 HBURS

FAILURE RATE DETERMINATION MOTOROLA, INC.

FREG SYN 1 (XMT2) MODULE PRBJECT 3995-113

49DEL A/T UNIT

DATE

F. R. FAILURES PER MILLIBN HRS. BASIC 71. C TEMP STRESS IN APR 21,171

NOTES

SM-188 SOURCE 217A €900€ 19.67999 8 • 80000 15.13600 1.51050 20.00000 •08580 43.25998 7-17500 4.07800 1.05765 FAILJRE RATE • 22000 00000 •02920 • 41000 1.25000 .22000 •00036 1.03000 • 41000 •00962 FACTBR 5.00 10.00 PERCENT 8.0 *** RESISTOR, FIXED CARBON COMPOSITION TRANSISTUR, SILICON VPV. 0-1 WATT INTEGRATED CIRCUIT, LINEAR COMPONENT DESCRIPTION RESISTOR, VARIABLE, 10-TURN DIBDE, SILICEN, 0-1 MATT CAPACITURA MICAA CM DIBDE, HOT CARRIER CAPACITON, CEN, CK TRANSFORMER, KF COIL, RF

121.58287 FAILURES PER MILLION HOURS FOTAL FAILURE RATE EQUALS

8224.8398 HBURS MEAN TIME BETWEEN FAILURES EQUALS

F-121

MOTOROLA, INC. FAILURE RATE DETERMINATION

49DEL AZT UNIT	
	71 €
FREG SYN 2 (REC)	TEMP
MODULE	
PRBJECT 3995-113	DATE APR 21, 71

	,	STRESS IN	¥ (DISABIC	FAILURES PER	F.R.	
רפיירטאבאן טבטראזין זפיא	.3	アドドト	THILLY A	FAILURE KATE	MILLION HAS.	SBURCE	NOTES
CAPACITOH, CER, CK	22.0	90	5.00	29600	1.05762	47.10	
CAPACITOR, MICA, CM	16.0	Y	15.00	16000			
) i	0000	95000	00000	<1/4	
רסורי אר	×	သ	8 • 60	• 22000	15-13600	217A	
DIGDE, HOT CARRIER	12.0	20	3.50	1.03000	43.25993	2174	
DIBDE, SILICBN, 0-1 MATT	2.0	၁၄	3.50	•41000	7.17500	217A	
INTEGRATED CIRCUIT, LIVEAR	2.0	50	1.00	• 40000	• 800UD	21.7A	
RESISTOR, FIXED CARBON COMPOSITION	57.0	50	10.00	• 02650	1.51050	217A	
TRANSISTOR, SILICON NPV. 0-1 WATT	0.9	50	8.00	• 41000	19.67999	217A	
TRANSISTUR, SILICEN PNP, 0-1 ATT	5.0	5C	8 . 00	1.25000	20.00000	217A	
TAANSFORMER, RF	O • 4	50	10.00	• 22000	8 - 80000	217A	
RESISTOR, VARIABLE, 10-TURN	1.0	5 در	2.00	2.03900	4.07800	SM-188	
CONNECTOR, RF	3.0	20	00 • *	00000	• 48000	217A	
CONNECTOR, 15 PINS	• 5	20	6.00	•34300	1.02900	217A	

S

123.09186 FAILURES PER MILLION HOURS TOTAL FAILURE RATE EGUALS

MEAN TIME BETWEEN FAILURES EQUALS 8124.0117 HBJRS

MBDEL AZT UNIT MODULE CARRIER IG/VCB PRBJECT 3995-113 DATE APR 21, 71

71. C TEMP

		TRESS IN		BASIC	α.	P. 4.	
COMPONENT DESCRIPTION	¥T.	PERCENT	FACTOR	FAILURE RATE	MILLION HAS.	SBURCE	NOTES
CAPACITHE, VAN AIR. CT	0	r.		0.7.2	ď		
	,)		5	つつきれます	4 / T U	
CAPACITUR, CER, CK	i	09	-	• 00962	3.46140	217A	
CAPACITER, MICA, CM	14.0	9	15.00	•00036	•07507	217A	
COIL, RF	•	2 0	•	• 25000	11.35200	217A	
	3.0	5 0	4.00	00040	• 48000	217A	
	សិ	50	6.30	•18200	•54603	217A	
	5.0	50	3.50	• 41000	•	217A	
INTEGRATED CIRCUIT, DISITAL	•	2 0	1.00	• 40000	1.20000	217A	
	19.	2 0	1.00	00004.	•	217A	
S4 RESISTUR, FIXED CARBON COMPOSITION	80.	ည	10.00	• 02650	2.12000	217A	
RESISTOR, FIXED METAL FILM		50	•30	•24850	•	217A	
RESISTOR, WW VAR. LEAD SCREW	•	2 0		•17075	•	Ō	
TRANSISTOR, SILICON NPUL 0-1 MATT	•	50	•	• 41000	•	217A	
ZENER DIBDE	3.0	50	3.00	1.25000	11.25000	217A	
DIBDE, HOT CARRIER	0.+	50	•	1.03000	14+42000	217A	
TRANSFORMER, RF	•	50	•	• 22000	00004 • 4	217A	
CRYSTAL, GUARTZ	•	50	1.00	• 05000	c0090 ·	217A	
CAPACITON, T C CEN, CC	0.4	50	•	•06200	1.24000	217A	
CAPACITOR, VAR GLASS, PC	1.0	50	20.00	• 24250	4.85000	217A	
•	•	20	1.00	4	•24700	217A	
S+ RESISTOR, FIXED METAL FILM	2.0	20	• 30	• 24850	• 00149	217A	

98.60519 FAILURES PER MILLION HOURS 10141.4531 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FAILUNE RATE EGUALS

MOTOROLA, INC. FAILURE RATE DETERMINATION

		F.R. SBURCE	2174	217A	217A	217A	217A	217A	217A	RADC	217A
LINO		FAILURES PER MILLION ARS.	2.21145	• 02145	1.02900	10.04500	1.20000	7.60000	2.08740	3.07350	3.28000
MODEL AZT UNIT	71. C	BASIC FAILURE RATE	.03962	•00036	.34300	• +1000	00004.	0000+•	.24850	•17075	•41000
OΥ		KACT9R	5•00	15.00	6.00	3.50	1.00	1.00	• 30	18.30	8.33
CODE DETECTOR	TEMP	STRESS IN PERCENT		9		50	၁၄	50	2 0	50	ည့
E C80		SYTO	0.94	0.4	r.	7.0	3.0	19.0	28.0	1:0	1.0
PRBJECT 3995-113 MBDJLE	DATE APR 21, 71	COMPONENT DESCRIPTION	CAPACITUR, CEN, CK	CAPACITURA MICAA CM	CONVECTOR, 15 PINS	_		VTEGRATE		¥	TAANSISTOR, SILICON YPN, 0-1 AATT

SJIAN

30.54776 FAILURES PER MILLION HOURS TOTAL FAILUME RATE EQUALS

MEAN TIME BETWEEN FAILURES EQUALS 32735.6211 HOURS

0 4

FAILURE RATE DETERMINATION MOTBRELA, INC.

MODULE CACU (DIGITAL) PREJECT 3995-113

APR 21, 11 DATE

MEDEL AZT UNIT

71. C

TEMP

SOURCE F . R. 217A 217A 2174 2174 217A 2174 2174 FAILURES PER MILLION HRS. .96000 •15500 1.43100 5.67600 1.44225 28.39999 •03218 BASIC FAILURE RATE .22500 .02920 -03952 643635 .00310 •00036 ·22000 FACTBR 1.00 10.00 000.9 5.00 8.60 STRESS IN PERCENT 7200 6.0 0.9 3.0 RESISTOR, FIXED CARBON COMPOSITION CAPACITUR, CEN, CK INTEGRATED CINCUIT, DISITAL RELAY, HALF CRYSTAL CAN COMPONENT DESCRIPTION CAPACITOR, MICA, CM CONNECTOR, RF CONNECTOR, 36 PINS COIL, RF

VOTES

41.77138 FAILURES PER MILLION HOURS TOTAL FAILURE RATE EGUALS

23939.8359 HOURS MEAN TIME BETWEEN FAILURES EQUALS

MOTGROLA, INC. FAILURE RATE DETERMINATION

MADEL AZT UNIT	
o _r	71. C
CL9CK IN DETECT9:	TEMP
CL9CK	
MODOLE	
3995-113	DATE APR 21,171
PRBJECT	DATE

COMPONENT DESCRIPTION	VT0	STRESS IN PERCENT	FACTOR	BASIC FAILURE MATE	FAILURES PER MILLIBN HRS.	SBURGE	0 L L D N
CAPACITUR, VAR AIR, CT	1.0	50	1.00	•24700	• 24700	2174	
CAPACITUM, CEN, CK	36.0	50	2.00	• 02425	4 • 36500		
K	10.0	50	15.00	• 00537	• 80550	217A	
	9	50	8 • 60	• 22000	11.35200	217A	
	3.0	50	4.00	.04000	• 48000	-	
CONNECTOR, 15 PINS		50 50	00.9	• 34300	1.02900	17	
DIBDE, SILICON, 0-1 HATT		50	3.50	• 41000	2.87000	-	
INTEGRATED	12.0	20	1.00	000004.	4 • 80000	17	
FIXED CARBB	•	ည	10.00	• 02650	1.27200		
FIXED METAL FILM	13.0	ე <u>ი</u>	• 30	• 24850	• 96915	-	
RESISTOR, WH	1.0	50	18.00	.17075	•	2	
TANSFORMER,	•	50	•	• 22000	•	-	
TRANSISTUR, SILICON NPV. C-1 AATT	0.0	20	8 • 00	• 41000	6 5 5 6 0 0 0	217A	
ZENER DIBD	•	5 5	•	1.25000	-	217A	
	4	50	3.50	1.03000	14.42000	217A	
CAPACITOR, T C CER, CC	•	50	5.00	•06200	1.24000	217A	
CAYSTAL, QUARTZ	2.0	50	1.00	• 05000	0,040.	217A	

70.47304 FAILURES PER MILLIBN HBURS 14189 8203 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FAILURE RATE EQUALS

MOTOROLA, INC. FAILURE RATE DETERMINATION

Account h

YBDEL ALT UNIT MODULE CLOCK PHASE CONTROL PRBJECT 3995-113

71. C TEMP DATE APR 21,171

	OTY	STRESS IN	FACTBR	BASIC FAILURE RATE	FAILURES PER MILLION ARS.	F + 3.	S LA CONTRACTOR
				מורמעל אינו	• 6 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	dar coc	NO IE
	38.0		5 • 30	•00962	1.82685	C1/A	
	*	09 0	15.00	• 00036	• 021 45	2174	
	ທີ) 5¢	8.60	• 22000	9 • 46000	217A	
	1.	50	3.50	• 41000	1 • 43500	2174	
	**	50	1.00	00004.	1.60000	2174	
	12.	50	1.00	00004.	4 • 80000	2174	
FIXED CARBON COMPOSITION	28•	90	10.00	• 02650	•74200	2174	
	100	50	• 30	. • 24850	•74550	217A	
VAR. LEAD SCREW ACT.	-	50	18.00	.17075	3.07350	RADO	
	5.	50	10.00	• 22000	11.00000	217A	
TRANSISTOR, SILICON APA, 0-1 MATT	7	50	8.00	• 41000	3.28000	217A	
	*	50		1.03000	14.42000	217A	
	•	20	2.00	• 06200	2.48000	2174	
	*	0 50	1.00	•02000	00000	217A	

54.96423 FAILURES PER MILLIBN HBURS 18193.6484 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FAILURE RATE EQUALS

MOTOROLA, INC. FAILURE RATE DETERMINATION

		NOTES				
		F.R. Søurce	217A	217A	217A	217A
MADEL POSITIONING SET		FAILURES PER MILLION HRS.	2.88000	2 • 18400	6.17400	11.02500
MADEL PAS	71• C	BASIC FAILURE RATE	00000	.13200	•34300	1.22500
ARNESS		FACTBR	00 • 4	00.9	00.9	00.9
RTU CABLE HARNESS	TEMP	STRESS IN			ე ე	
MBJULE RT		PT0	18.0	2.0	3.0	1.5
PR9JECT 3995-113	DATE APR 21,171	COMPONENT DESCRIPTION	CONVECTOR, RF	CONVECTOR, 8 PINS	CONNECTOR, 15 PINS	CONNECTOR, 36 PINS

22.26300 FAILURES PER MILLIBN HBURS 44917.5742 HBURS MEAN 114E BETWEEN FAILURES EQUALS TOTAL FAILURE RATE EQUALS

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YOTGRALA, INC. FAILURE RATE DETERSINATION

1 1 1

MODEL POSITIONING SET 71. C TEMP MODULE RCDU-UPU PRBJECT 3995-113 DATE APR 21, 71

		STRESS IN	Y	3ASIC	FAILURES PER	C.	
COMPONENT DESCRIPTION	OTY	PERCENT	FACTOR	FAILURE RATE	MILLIBY HRS.	SOURCE	NOTES
CAPACITUR, CER, CK	68.0		5.30	-00062	3.26913	217A	
CAPACITOR, T C LER, CC	2.0	50	5.33	• 06200	•62300	217A	
CAPACITOR, MICA, CM	20.0		15.00	• 00036	• 10725	217A	
CAPACITUR, SLD TANT, CSR	5.0		1.00	•75050	• 37525	217A	
COIL, AUDIO	1.0		10.00	.22750	2.27500	2174	
COIL, RF	3.0		6.60	•22000	5.67600	217A	
INTEGRATED CIRCUIT, DISITAL	41.0	20	1.00	00004.	16.39999	217A	
INTEGRATED CINCUIT, LINEAR	12.0		1.00	00004.	4.80000	2174	
SA RESISTORA FIXED CARESA COMPOSITION	54.0		10.00	• 02650	1.43100	2174	
RESISTOR, FIXED METAL FILM	9.0		.30	.24850	.59640	217A	
-	5.0		10.00	.22000	00004 • 4	217A	
TRANSISTOR, SILICON APA, C-1 EATT	1.0	20	8.00	•41000	3.28000	217A	
•							

43.22995 FAILURES PER MILLION HOURS TOTAL FAILURE RATE EQUALS

MEAN TIME BETHEEN FAILURES EQUALS 23132-1094 HOURS

MUTBROLA, INC. FAILURE RATE DETERMINATION

PM6JECT 3995-113 M9JULE		JPJ PWR SUP		490E- 298	POSITIONING SET	
DATE APR 21, 71		TEMP		71• C		
NOTE OF SCRIPTION	¥10	STRESS IN	Y 4	BASIC	FAILURES PER	X 0
					ורר ופוחוו	שמשרב
	•		1.00	.75050	0700++	17
-	5.0		6.00	•16750	•	17
CAIL, AUDIB	1.0			• 22750	•	17
	15.0		3.50	00014.	21.52499	
	1.0			01500	. •	17
FIXED CARBS	19.0		0	•02650	• 50350	
RESISTOR, FIXED METAL FILM	2.0			.24850	• 001 • 9	-
	1.0		10.00	• 22000	2.20000	17
STAT Z	0.4		8.33	-	13 12000	17
			8.33	.82000	6.56000	
TRANSISTOR, SILICON PNP, 0-1 AATT	3.0	50	8.00	'n	30.00000	217A
ZENER DIBDE, 0-1 MATT	3.0		3.00	1.25000		17
CAPACITOR, CEN, CK			5.00	9	•	
CONNECTOR, 15 PINS	•		00.9	•34300	1.02900	2174

NOTES

S PER MILLION HOURS	
MILL	
PER	HBURS
1.89345 FAILURES	10882-1680 HBURS
.89345	
91	EGUALS
E RATE EGUALS	MEAN TIME BETWEEN FAILURES EQUALS
RATE	EEN F
URE	BETW
FAIL	T11E
191AL FAILURE	MEAN

I			
T			
-		L 13	
• •		SEPIN	
		951718	
		48DEL POSITIONING SET	
		ቻ	U
	7611		71. C
	MOTOROLA, INC. AILURE RATE DETERMINATION	CONTRB	TEMP
	MOTORBLA, INC. RATE DETERMIN	WORD	-
	MOTE RAT	DPU	
	FAILU	MODULE DPU WORD CONTROL	
		13	71
		PRBJECT 3995-113	APR 21, 171
		JECT	FE AP
		9	DATE

COMPONENT DESCRIPTION	YTO	STRESS IN K GTY PERCENT FACTOR	FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITUM, CEM, CA CONNECTOR, 36 PINS INTEGRATED CIRCUIT, DISITAL S& RESISTOR, FIXED CARBUN COMPOSITION	15.00	9000	5.00 6.00 1.00	.00962 1.22500 .40000 .02650	.72113 7.35000 17.59999 .13250	217A 217A 217A 217A	

25.80360 FAILURES PER MILLIBN HOURS 38754.2734 HBURS TOTAL FAILURE RATE EQUALS 25.

MOTORCA, INC. FAILURE RATE DETERMINATION

	NG TES
	F.R. SOURCE 217A 217A 217A 217A 217A
49DEL POSITIONING SET	FAILURES PER MILLIBN HRS. .76920 7.35040 18.79999 .47700
υ •	BASIC FAILURE RATE • 00962 1•22500 • 40000
PUT CTR.	FAETBR 5.00 1.00 10.00
DPU MSG BUTPUT CTR_	STRESS IN PERCENT 60 50 50 50
LLI	314 S 16.0 17.0 18.0
PRBJECT 3995-113 MBDUL DATE APK 21,171	CAPACITUR, CEK, CK CONNECTUR, 36 PINS INTEGRATED CIRCUIT, DISITAL S4 RESISTOR, FIXED CARBUN CUMPOSITION

1				NOTES			
<u>I</u> -				F.R. SBURCE	217A 217A	217A 217A	
)ET		PER.			
E construction of the cons		5 ENIN		FAILURES PER MILLION HRS.	•72113 7•35000	18.39999	
		SITIO				00	
		MODEL POSITIONING SET		IC E RATE	• 00962 • 225JD	• 40000	
		¥	U	BASIC FAILJRE RATE	.00962 1.22500	• • •	
	VEITI	5 ST	71. 6	FACTOR	5.33	10.00	
	INC.	ASMBL	TEMP	Z	υ 3	101	
	MBTBRBLA, INC. RATE DETERMIN	DPJ DATA ASMBLR & ST	-	STRESS 1 PERCENT	6. 50	50	
	MBTBRBLA, INC. LURE RATE DETERMINATION	DPJ		S YTO	15.0	0.9	
	FAIL	HEDULE				Z 60	
			17			USITI	
		PRBJECT 3995-113	DATE APR 21,171	PTION		ISITAL N COME	
		JECT 3	E AP4	CBMPBNENT DESCRIPTION	CK	CARBB	
		PRB	DAT	NENT	CER,	FIXED	
				СВМРЕ	CAPACITUM, CEM, CK CONNECTUM, 36 PINS	INTEGRATED CIRCUIT, JISITAL RESISTOR, FIXED CARBON COMPOSITION	
I					CAPA	INTE SA RESI	
						S	

26.63011 FAILURES PER MILLIBN HBURS TOTAL FAILURE RATE EQUALS

MEAN TIME BETWEEN FAILURES EQUALS

37551.4727 HBURS

MOTOROLA INC. FAILURE RATE DETERAINATION

	NOTES	
	F.R. SBURCE	2174 2174 2174 2174
MBDEL POSITIONING SET	FAILURES PER MILLIBN HRS.	.67305 7.35000 17.59999 .53000
E3	AASIC FAILURE RATE	. 000962 1. 22500 . 40000 . 02650
0EC60ER	FACTOR	10.000 10.000 10.000
OPJ COMMAND DECGOER TEMP 71	STRESS IN PERCENT	တက္ကလ ၁၁၁၁၁၁ ၁၈၈၈၈
Li	S Y T	00000 00000
PREJECT 3995-113 M0JULI	COMPOSENT DESCRIPTION	CAPACITBA, CER, CK CONNECTUR, 36 PINS INTEGRATED CIRCUIT, DISITAL RESISTOR, FIXED CARBON COMPUSITION CAPACITOR, SLD TANT, CSR

26.22807 FAILURES PER MILLIBN HBURS 38127.0859 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FAILURE RATE EGUALS

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MOTORDA INC. FAILURE RATE DETERMINATION

MODEL POSITIONING SET	U
183ULE CABLE HARNESS-3PJ	TEMP 71. C
PR9JECT 3995-113 M6	DATE AP4 21,171

NOTES	
F.R. SBURCE	217A 217A 217A 217A
FAILURES PER MILLIBY HRS.	.32000 1.02900 51.45001 1.45800
BASIC FAILURE RATE	.04000 .34300 1.22500 .48600
FACTBR	4 9 9 9 0 0 0 0
STRESS IN K	9999 9999
S	0 v 0 v
COMPONENT DESCRIPTION	CONVECTUR, RF CONVECTUR, 15 PINS CONNECTUR, 36 PINS CONNECTUR, 20 PINS

54.25700 FAILURES PER MILLIBN HBURS TOTAL FAILUNE RATE EGUALS

MEAN TIME BETWEEN FAILURES EQUALS

18430.7969 HBURS

MOTORDIA, 1.C. FAILURE RATE DETENTINATION

		VOTES														
		F. A. SBURCE	-	-	17	17	17	1	17	17	217A	17	17	17	17	17
		FAILURES PER MILLIBY ARS.	0.5034.	.685	2.27500	21 • 52 499	• 15500	110		\sim	S	ល	30 • 0000	11.25000	• 36375	1.02900
	U	BASIC FAILURE RAFE	.75050	.16750	. 22750	• 41000	.03310	• 02650	• 24850	• 22000	.41000	·82030	1.25000	1.25000	•02425	•34300
	71•	FACTOR	1.33	5.33	10.00	3.50	50.00	6	•33	•	8.00	8.00	•	•	•	•
	TE SE	STRESS IN PERCENT									ņ					
1		¥16	0.9	•	1.0	•	•	•	•		4 • 0	1.0	•	•	•	ທີ
	DATE AP4 21,171	COMPONENT JESCRIPTION	CAPACITORS SLO TANTS CSR	CAPACITOR, FOIL TANT, CL	COIL, AUJIS	DIBDE, SILICBN, C-1 AATT	RELAY, HALF CRYSTAL CAN	RESISTORY FIXED CARBON COMPOSITION	RESISTOR, FIXED METAL FILM	TRANSFORMER, PONER	TRANSISTUR, SILICEN VENN C-1 VATT	TRANSISTUR, SILICAN NPN, 1-50 WATT	TRANSISTOR, SILICEN PUP, DAI MATT	ZENER DIBDE, 0-1 AATT	CAPACITOR, CER, CA	CONVECTOR, 15 PINS

24

F-136

92-11298 FAILURES PER MILLION HOURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FAILURE RATE EGUALS

10856.2305 HBURS

MOTORSLA, INC. FAILURE RATE DETERMINATION

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1

18DEL AIRBBRNE PSS SET	
	71. C
AIRBORNE MEMBRY	TEMP
MEDULE	
PHBJECT 3995-113	DATE AP4 21,171

COMPONENT DESCRIPTION	YTO	STRESS IN	FACT98	BASIC FAILURE RATE	FAILURES PER MILLION HASS	SBURGE	200
		•					
CAPACITBA, CER, CK	0.0		رد• خ	45450	•60625	217A	
CAPACITOR, SLD TANT, CSR	17.0		1.00	•73050	1.27565	217A	
	9.0		6.00	• 22200		2174	
CONNECTOR, 20 PINS	15.0	50	00.9	• 48600		217A	
DIBDE, SILICBN, 0-1 AATT	50.0	50	3.50	•41000	71.75000	217A	
INTEGRATED CINCUIT, DIGITAL	41.0	50	1.00	00004.	w	217A	
_	41.0	20	1.00	00004.	·	217A	
RESISTOR, FIXED HETAL FILM	92.0	50	• 30	• 24850	·	217A	
	21.0	90	3.00	1.25350		217A	
TRANSISTUR, SILICUN VPV. 0-1 WATT	14.0	50	8 • 00	•41000	45.92000	217A	
	2.0		3.00	1.25000	7 • 50000	217A	
CORES, FERRITE		50	1.00	•00005	• 49922	217A	
CORES, FERRITE	9999.0	50	1.00	• 00005	1.59998	217A	

303-50781 FAILURES PER MILLIBN HBURS TOTAL FAILURE RATE EQUALS

MEAN TIME BETWEEN FAILURES EQUALS 3294-8079 HBURS

MOTORDA INC. FAILURE RATE DETERMINATION PREJECT 3995-113 MODULE FILTER & AIRBERVE MAD DATE APY 21,171 TEMP 71. C

MADEL POSITION SETANIR

CAPACITUR, VAR AIR, CT

STRESS IN C BASIC FAILURES PLR OTY PERCENT FACTOR FAILURE RATE MILLION HRS.

VUTES

F.A. SBURGE

2174

1.23500

•24700

1.30

50

3.0

TOTAL FAILURE RATE EGJALS

1.23500 FALLURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EQUALS 809716-8125 HOURS

MOTORGLA, INC. FAILURE RATE DETERMINATION

100

		NOTES				
		F.R. SBURCE	217A	217A	217A	217A
MODEL POSITION SETARIS		FAILURES PER MILLION HRS.	20.81200	1.09200	7 • 35000	31.50000
YBDEL PBS	71• C	BASIC FAILURE RATE	• 22000	•18200	1.22500	•25000
BNITER		FACT93	ô•60	6.00	6.30	18.00
CONTROL & MONITOR	TEMP	STRESS IN	50	50	50	20
Madule Can		S *T 0	11.0	1.0	1.0	7.0
PRBJECT 3995-113	DATE APR 21,71	COMPONENT DESCRIPTION	כפורי אל	CONNECTOR, 8 PINS	CONNECTOR, 36 PINS	SWITCH, TOGGLE OR PUSHBUTTON

60.75398 FAILURES PER MILLIBN HBURS TOTAL FAILURE RATE EQUALS

16459.8242 HBURS

MEAN TIME BETWEEN FAILURES EQUALS

MOTORGIA, INC. FAILURE RATE DETERMINATION

MODEL AIRBORNE DOS SET 71. C MEDULE RUBIDION FREG STO TEMP PRBJECT 3995-113 DATE AP4 21, 171

NUTES		
F.R. SBURCE		121
FAILURES PER MILLION HRS.	266650 1 1 266640 1 266640 1 266640 1 266640 2 2 35141 2 2 35141 2 35141 2 35141 3 35141 3 35140 3 36000 4 4 8 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	
BASIC FAILJRE RATE	1	800
KACT9R		000
RESS IN	222222222222222222222222222222222222222	222
ST GTY P		
COMPONENT DESCRIPTION	CAPACITBY, ALUX ELECT, CE CAPACITBY, GLASS, CY CAPACITBY, GER, CK CAPACITBY, MICA, CM CAPACITBY, MICA, CM CAPACITBY, MICA, CM CAPACITBY, SLD TANT, CSR CAPACITBY, VAR CER, CV CAPACITBY, VAR CER, CV CONNECTER, S PINS CONNECTER, S PINS CONNECTER, S PINS CAYSTAL, DUARTZ DIBDE, SILICON, 1-50 WATT FILTER, FEED THRU FUSE INTEGRATED CIRCUIT, LINEAR METER METER METER METER METER METER METER METER MESSISTOR, MON-WY VAR. LEAD SCREW ACT. SAITCH, TOGGLE BR PUSHBUTTON TARRESTED TO A RECOMMENDED RESISTORY MAR. LEAD SCREW ACT. SAITCH, TOGGLE BR PUSHBUTTON TARRESTED TO TARRESTED TO STREW MESSISTORY MAR. LEAD SCREW ACT. SAITCH, TOGGLE BR PUSHBUTTON	TAANSFORMEN, POWER TRANSFORMEN, NF

217A	217A	2174	2174	217A	217A	217A	217A	217A
7.32000	17.60001	66664.69	22 • 39999	26 • 8 4 3 3 3	9 • 76000	1.96000	10.08000	1.26000
•30500	1.10000	•14000	• 23000	•30500	•61030	.14000	• 42000	• 42000
8 • 00	8.30	8.00	8 • 00	8 • 00	8•00	3.50	3•00	3.00
10	10	10	10	10	10	٦ ا	<u>ا</u>	10
3.0	S•0	62.0	10.0	11.0	o•0	0 • +	∂• ®	1.0
FIELD EFFECT	RANSISTUR, GERMANIUA DA	RANSISTAR, SILICHA	SILICON APA	RANSISTAR, SILICON PAP	SILICEN PUDI	VARICAP	DISDE, 0-1 W	ZENER DIGDE, 1-50 WATT
	a distribution			9,	i. ia		1.00	But!

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Toronto d

1321.14771 FAILURES PER MILLIBN HBURS TOTAL FAILUNE RATE EQUALS

756.9175 HBURS

MEAN TIME BETWEEN FAILURES EQUALS

MOTOREALE INC. FAILURE RATE JETERMINATION

PRBJECT 3995-113	MODULE BUTSIDE CABLES	MBDEL LAP	MBDEL LAPOS SYSTE1		
DATE AP4 21, 71	TEMP 71. C	U			
CHMPBNENT DESCRIPTION	STRESS IN A GIY PERCENT FACTOR	BASIC FAILJRE RATE	FAILURES PER MILLIBN 1486.	F. R. SBURGE	NOTES
CONVECTOR, RF CONVECTOR, 8 PINS	1.0 50 4.00 2.0 50 6.00	.04000 .18800	•1600J 2•1840J	217A 217A	

MOTORCÍA, INC. FAILURE RATE DETERMINATION

TOTAL OF ALL MODULES PRBJECT 3995-113 71. C

TEMP

DATE APR 21,171

3104+39087 FAILURES PER MILLION HOURS

322.1243 HBURS

MEAN TIME BETWEEN FAILURES EQUALS

TOTAL FAILURE RATE EGUALS

F-143

APPENDIX F-4.5

TYPICAL OPERATION

RELIABILITY PREDICTION DATA SHEETS

REFERENCE POSITION SET AN/ASQ-148

ENVIRONMENT: AIRBORNE

TEMPERATURE: +50°C

STRESS LEVELS: 30% (ASSUMED) EXCEPT

RUBIDIUM STANDARD STRESSES

AT 10% (ASSUMED)

MOTOREA, INC. FAILURE RATE DETERMINATION

MBOULE POWER CONVERTER PRBJECT 3995-113

TEMP

MODEL AZT UNIT

50 °C

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DATE APR 21,171

COMPONENT DESCRIPTION	¥T@	STRESS IN PERCENT	FACT93	BASIC FAILURE RAIE	FAILURES PER MILLION HRS.	F.R. SBURCE	NOTES
	0.00		(C)	0.640	Cr960•	217A	
CAPACI DAY CEAN CN	2				, , , ,		
CAPACITURA, SLO TANTA CSR	9.0	30	1.00	.17030	• 15300	217A	
	0.0	30	8 - 30	.03650	1.38403	217A	
	000	30	8 • 60	• 22000	4 • 54080	217A	
DIADE	0.00	30	3.50	•25500	7-14000	217A	
O TOOL OF THE OWN THE OWN	1.0		12.00	• 43000	5 16000	217A	
	0.6		1.00	•05400	+21600	217A	
$-\infty$	0		10.00	00400	•03500	217A	
	•		08.	•17000	• 2040J	217A	
THE STATE OF THE S	1.0		10.00	· 22000	2.20000	217A	
	1.0		8 . 00	• 25500	2 • 0 4000	217A	
TIVE COLUMN SOLUTION STATEMENT A	1.0	30	8.00	•51000	4.08000	217A	
TOANSTARM SITTEMS	N.	30	8 000	•67000	10 • 72000	217A	
O-1 WATT	1 77	30	3.00	•77000	2.31000	217A	
CONTROL OF PINS	100	30	9	.18200	1.09200	217A	

41.36771 FAILURES PER MILLION HOURS 44.00000 FAILURES PER MILLION HOURS 24173.4453 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FAILURE RATE EGUALS DESIGN FAILURE RATE GOAL

MOTOROLA, INC. FAILURE RATE DETERMINATION

MODEL AZT UNIT	
	50° C
	TEMP
RF/1F	
MBOULE	
PRAJECT 3995-113	DATE APR 21,171

NUTES									-					
F . R . SOURCE	217A	217A	217A	217A	217A	217A	217A	217A	217A	217A	217A	217A		
FAILURES PER MILLIBY HRS.	.48000	• 021+5	1 • 8920.0	• 56000	1.02900	2 • 00000	• 155uJ	• 07600	7 - 86000	2.73000	1.32000	• 07000		
BASIC FAILURE RATE	07900	• 60071	• 22000	0000+0•	•34300	00000	•00310	00400	39 • 30000	•65000	• 22000	•03200		
IN A FACTOR	5.00	15.00	8 • 60	4.00	6.33	1.00	50.00	10.00	2.00	3.50	10.00	1.00		
STRESS IN PERCENT	30	36	30	30	3C	30	30	30	ري ن	30	30	30		
SYTO	15.0	2.0	1.0	3.5	ů	5.0	1.0	19.0	1.0	7.	5.0	2.0		
COMPONENT DESCRIPTION	CAPACITUM, CER, CK	CAPACITUR, MICA, CM	COIL, RF	CONNECTOR, RF	CONNECTUR, 15 PINS	INTEGRATED CIRCUIT, LINEAR	RELAY, HALF CRYSTAL CAN	S4 RESISTOR, FIXED CARBON COMPOSITION	SS RESISTORS NON-WH VAR. L. S. ACT.	S. DIBUE, HUT CARRIER	S. TRANSFORMER, RF	CAPACITON, VAR AIR, CT	·-1	46

NOTE1: FACTOR OF 0.1 APPLIED TO FAILURE RATE DUE TO NO FIELD ADJUSTMENTS

18.19342 FAILURES PER MILLION HOURS

19.00000 FAILURES PER MILLION HOURS

54964.9219 HBURS

MEAN TIME BETWEEN FAILURES EQUALS

DESIGN FAILURE RATE GOAL

TOTAL FAILURE RATE EQUALS

MOTGRELA, INC. FAILURE RATE DETERMINATION

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MODULE	
3995-113	AFK 21, 171
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	}	STRESS IN	2 to 4 to 5	BASIC	FAILURES PER	T	1
College Description	3	というとう	TACION		SYL NEITH	SOURCE	NOTES
CAPACITUM, CEM, CK	01.0	30	5.30	34900+	1.95200	21/A	
S. COIL, RF	0 • 1 7		8 • 60	• 220uu	13.62241	217A	
CONNECTOR, RF	1.5		4.00	00070	• 240co	217A	
DIBDE, HOT CARRIER	3.0		3.50	•65000	6 • 82500	217A	
DIBUE, SILICBN, U-1 MATT	3.8		3.50	• 25500	7 • 1 4 0 0 0	217A	
S. RESISTUR, FIXED CARBON COMPOSITION	33.0		10.00	00400	•13200	217A	
TRANSFORMER, KF	10.0		10.00	• 22000	22,00000	217A	
S. TAANSISTUR, FIELD EFFECT	9.6		8.00	•67000	14.47200	217A	
TRANSISTOR, SILICSN VPV. 0-1 MATT	1.0		8 • 00	• 25500	2 • 0 4 3 0 0	217A	
S. TRANSISTUR, SILICUN VPV. 1-50 HATT	9.6		8 • 00	•51000	11.016.1	217A	
CONNECTOR, 36 PINS	r.		9.00	1.22500	3+67500	217A	

83.11436 FAILURES PER MILLION HOURS TOTAL FAILUNE RATE EGUALS

MEAN TIME BETWEEN FAILURES EQUALS 12031.6133 HBURS

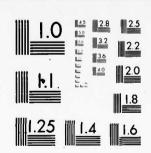
95.00000 FAILURES PER MILLION HOURS DESIGN FAILURE RATE GOAL MOTOROLA INC SCOTTSDALE ARIZ GOVERNMENT ELECTRONICS DIV F/G 17/3
LAPPS INTERIM TECHNICAL REPORT, APPENDICES, (U)
DAAK02-71-C-0022
NL

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ADDOCTORS

ADDOCTORS

DESCRIPTION

4 OF 4 ADA047145



MICROCOPY RESOLUTION TEST CHART NATIONAL BUREAU OF STANDARDS 1963 A

MOTORIA INC. FAILURE RATE DETERMINATION

50° C
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DATE APR 21, 171

	0,	STRESS IN	×	BASIC	FAILURES PER	P . K.	
COMPONENT DESCRIPTION	GTY	PERCENT	FACTOR	FAILURE RATE	MILLION HAS.	SBURCE	NOTES
CAPACITON, CEM, CA	6.9		5.00	04900•	•19200	217A	
CAPACITUR, SLD TANT, CSR	8.0	30	1.00	.17000	.C3#C3	217A	
COIL, RF	9		8.60	•22000	3.78400	E17A	
DIBOE, HBT CARRIER	8.0		3.50	•65000	18.20000	217A	
DIBDE, SILICON, 0-1 AATT	10.0		3.50	•25500	8 • 92500	217A	
INTEGRATED CINCUIT, LINEAR	0.8		1.00	00004 •	C2008 •	217A	
RELAY, HALF CRYSTAL CAN	3.0		50.00	•00310	• 46500	217A	
SA RESISTOR, FIXED CARBON COMPOSITION	30.0		10.00	00400	•12000	217A	
TRANSFORMER, KF	4.0		10.00	• 22000	8 - 80000	217A	
SA TRANSISTOR, SILICON APA, 0-1 MATT	10.0		8.00	•25500	6.12000	2174	
ZENER DIBDE, 0-1 MATT	1.0		3.00	•77000	2.31000	217A	

49.74994 FAILURES PER MILLION HOURS	20103.5234 HBURS	Soliday May 1114 and Shall 1147 GOOD CO
49.749	EQUALS	0000
TOTAL FAILURE RATE EQUALS	MEAN TIME BETWEEN FAILURES EQUALS 20103-5234 HBURS	DESTEN FATTINGE BATE COAL

49T9R9LA, INC. FAILURE RATE DETERMINATION

MADEL AZT UNIT MEDULE FREG SYN 1 (XMTR) PRBJECT 3995-113

DATE APR 21, 71

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NUTES

COMPONENT DESCRIPTION	QTY	STRESS IN	FACTBR	BASIC FAILURE RATE	FAILURES PER MILLISA HRS.	F.R. SBURCE
CAPACITON, CEN, CA	22.0	ာဗ	5.00	04900•	•70400	217A
CAPACITUR, MICA, CM	16.0		15.00	.00071	•17160	2174
COIL, RF	8		8.60	• 22000	15.13600	217A
S. DIBUE, HOT CARRIER	12.0		3 • 50	•65000	8 • 19000	217A
DIGDE, SILICON, 0-1 WATT	0.0		3.50	• 25500	4.46250	217A
	2.0		1.00	00004.	•80000	2174
S. RESISTOR, FIXED CARBON CUMPOSITION	57.0		10.00	00400	• 22800	217A
TRANSISTOR, SILICON NPV. 0-1 WATT	0.9		8 • 00	•25500	12.24000	217A
TAANSISTUR, SILICON PNP, 0-1 WATT	o•\ \ \		8.00	•67000	10.72000	217A
TAANSFORMERS AF	0.4		10.00	•22000	8 • 80000	2174
RESISTOR, VARIABLE, 10-TURN	1.0		2.00	1.51000	3.02000	SM-188

64.47203 FAILURES PER MILLION HOURS TOTAL FAILURE RATE EQUALS

15510.6016 HBURS MEAN TIME BETWEEN FAILURES EQUALS

66.00000 FAILURES PER MILLIBN MBURS DESIGN FAILURE RATE GOAL

MOTORELA, INC. FAILURE RATE DETERMINATION

MBDEL AZT UNIT 50 · C MSDULE FREG SYN 2 (REC) TEMP PRBUECT 3995-113 DATE APY 21,171

AT AND AD			STRESS IN	~	BASIC	FAILURES PER	F . K.	
معيشيم	COMPONENT DESCRIPTION	QTY	PERCENT		FAILJRE KAIE	MILLIBY ARS.	SOURCE	NOTES
والمنافع المنافع	CAPACITUR, CEM, CA	22.0		5.30	0.00640	.70*07•	217A	
	CAPACITOR'S MICAS CX	16.0	30	15.30	• 60071	.17163	217A	
E-partie		° ∞		5.60	• 22000	15.13600	217A	
S	S. DIBDE, HBT CARRIER	12.0		3.50	•65000	8 • 19000	217A	
o Caballa	DIBDE, SILICBN, 0-1 MATT	သ		3.50	•255vC	4 • 46253	217A	
-13-2	INTEGRATED CIRCUIT, LINEAR	2.0		1.00	00000	• 80000	217A	
5	RESISTOR FIXED CARBON COMPOSITION	57.0		10.00	00400	• 22800	217A	
100.1	TRANSISTOR, SILICON VPV. C-1 AATT	0.9		8.00	• 25500	12.24000	217A	
- Alian	TAANSISTUR, SILICEN DAD, C-1 AATT	S 8		8.30	.67000	10.72000	217A	
F-	TAANSFURMER, XF	0.4		10.00	• 22000	8 - 60000	217A	
-1	RESISTOR, VARIABLE, 10-TURN	1.0	30	2.00	1.51000	3.02000	SM-188	
50	CONNECTOR, RF	3.0	30	00.4	000+0•	• 48000	217A	
200.000	CONNECTOR, 15 PINS	លំ	30	00.9	•34300	1.02900	217A	

65.98102 FAILURES PER MILLION HOURS 66.00000 FAILURES PER MILLIUN HOURS 15155.8711 HBURS MEAN TITE BETWEEN FAILURES EQUALS TOTAL FALLURE RATE EGUALS DESISH FAILURE RATE GBAL

MOTORDA, INC. FAILURE RATE DETERMINATION

MEDULE CARRIER IG/VCS PROJECT 3995-113

50° C TEMP

MODEL AZT UNIT

DATE APR 21,171

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	COMPONENT DESCRIPTION	QTY	PERCENT	FACTOR	FAILURE RATE	MILLION HAS.	SBURCE	7.
(m	CAPACITURE VAR ATR. CT	0.0	(F	1.00	03500	0.020	4716	
		1			0000		7/13	
		78.0	J.	5.00	04900	2.30400	. 217A	
	CAPACITOR, MICA, CM	14.0	30	15.00	• 00071	•15015	217A	
53		0.9	30	8 • 60	• 22000	3.40560	217A	
		3.0	30	4.00	000400	• 48300	217A	
	CONNECTOR, 15 PINS	S.	ာဗ	00.9	•34300	1.02900	217A	
70.	DIBDE, SILICON, U-1 WATT	5.0	30	3.50	•25500	4 4 4 6 2 5 0	217A	
. 1	CIRCUIT,	3.0	30	1.00	• 40000	1.20000	217A	
67	INTEGRATED CIRCUIT, LIVEAR	•	3. 3.	1.00	00000	7 • 60000	217A	
S		80.0	30	10.00	20400	• 32000	217A	
	RESISTOR, FIXED METAL FILM		30	• 30	•17650	1.37700	217A	
۵	RESISTORS WW VAR. LEAD SCREW ACT.	3.0	30	18.00	00960•	5.18400	RADC	
Sz		•	30	8.00	•25500	3.06000	217A	
	ZENER DIBDE, 0-1 WATT	•	30	3.00	•77000	6.93000	217A	
	DIODE, HOT CARRIER	49	30	3 • 50	• 65000	9.10000	217A	
	TAANSFORMER, RF	5.0	30	10.00	•22000	4.40000	2174	
	CAYSTAL, GUARTZ	•	30	1.00	•02000	• 06000	217A	
	CAPACITON, T C CER, CC	4.0	30	2.00	• 00625	•12500	217A	
	CAPACITON, VAR GLASS, PC	1.0	30		•05850	1.17000	217A	
		1.0	30		•03500	•03200	2174	
24	RESISTOR, FIXED METAL FILM	5.0	30	• 30	•17000	•00102	217A	

52.46315 FAILURES PER MILLIBN HBURS TOTAL FAILURE RATE EGUALS

19060.9961 HBURS MEAN TIME BETWEEN FAILURES EQUALS

DESIGN FAILURE RATE GOAL

54.00000 FAILURES PER MILLION HOURS

MOTORGIA INC. FAILURE RATE DETERMINATION

MADEL AZT UNIT	
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CADE DETECTOR	TEMP
MODULE	
3995-113	210.71
PRBJECT	DATE APY 21, 7

			STRESS IN	¥	BASIC	FAILURES PER	× •	
	COMPONENT DESCRIPTION	⊅T©	OTY PERCENT FACTS	FACTBR	FAILURE RATE	MILLIBN 435.	SBURCE	NOTES
	CAPACITUM, CEM, CA	46.0		50 • 00	04900	1.47200	217A	
	CAPACITUM, MICA, CP.	0.4	30	15.00	• 60671	• 64595	217A	
	CONNECTURA 15 PINS	• 5		6.30	•34300	1.02900	217A	
S	S3 DIBDE, SILICBY, C-1 AATT	7.0		3.50	•25500	1.87425	217A	
	INTEGRATED CINCUIT, DISITAL	3.0		1.30	00004.	1.20000	217A	
S	S. INTEGRATED CIRCUIT, LINEAR	19.0		1.00	00000	2.28000	217A	
	RESISTOR, FIXED METAL FILM	28.0		• 30	•17000	1.42800	217A	
THE STATE OF THE S	RESISTORA WW VAR. LEAD SCHEM ACT.	1.0		16.00	00960•	1.72800	RADC	
	TAANSISTURE SILICON VPV. C-1 AATT	1.0		8.00	• 25500	2.04000	217A	

S PER MILLION HOURS	3S
9	JOH H
13.09411 FAILURES	76370-1875 HBURS
13.	EGUALS
TOTAL FALLURE KATE EQUALS	MEAN TINE BETWEEN FAILURES
KATE	EEN
URE	BETW
FAI	TIYE
TOTAL	MEAN

DESIGN FAILURE RATE GOAL

16.00000 FAILURES PER MILLIAN HBURS

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4935- 4/T UNIT	
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PRBJECT 3995-113	DATE AP4 21, 171

		,	STRESS IN	¥	BASIC	FAILURES PER	F.R.	
	COMPONENT DESCRIPTION	AT6	GTY PERCENT FACTOR	FACT93	FAILURE RATE	MILLION HRS.	SBURCE	NOTES
	CAPACITOR, CEN, CK	30.0		5.00	0,9640	c0096•	217A	
S	S+ INTEGRATED CIACUIT, JISITAL	71.0		1.00	000040	2.84000	217A	
	RELAY, HALF CHYSTAL CAN	1.0		50.00	.00310	•15500	2174	
S	S. RESISTOR, FIXED CARBON COMPOSITION	54.0	30	10.00	•00400	•21600	2174	
	CAPACITOR, MICA, CM	0.9		15.00	.00071	·06435	217A	
	COIL, RF	3.0		8 • 60	• 22000	5.67600	217A	
	CONNECTOR, RF	0.9		4.00	000+0•	• 96000	217A	
	CENNECTOR, 36 PINS	• 5		00.9	1.22500	3.67500	217A	

14.54630 FAILURES PER MILLION HOURS 20.00000 FAILURES PER MILLION HOURS 68745.9375 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FAILURE RATE EQUALS DESIGN FAILURE RATE GOAL

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PROJEC	DATE

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	COMPONENT DESCRIPTION	ů TY	PERCENT	FACTOR	FAILURE MATE	MILLIBY HAS.	SBURCE	
	CAPACITORS VAN AIRS CT	1.0		1.00	0.650.		2174	
						, , , ,		
	ことが	36.0		200	04900	1-15200	217A	
	CAPACITER, MICA, CP	10.0		15.00	·00C71	•10725	217A	
SS		0.9		8 • 60	• 22000	3•40560	217A	
	CONNECTOR, RF	3.0		4.00	00040.	• 480∪0	217A	
	CONNECTOR, 15 PINS	្ន		9.00	•34300	1.02900	217A	
	DIBUE, SILICBN, 0-1 MATT	o N		3.50	• 25500	1.78500	217A	
	INTEGRATED CINCUIT, LINEAR	12.0		1.00	00000	4.80000	217A	
St	RESISTOR, FIXED CARSS	48.0		10.00	004000	•19203	217A	
	FIXED METAL FILM	13.0		• 30	•17696	•66300	217A	
	RESISTOR, NE VAR. LEAD SCREW ACT.	1.0		16.00	00960•	1.72800	KADC	•
S	TRANSFORMER, 4F	0.9		10.00	• 22000	3.96000	217A	
F	TRANSISTBR, SILICEN APA, 0-1 AA	2.0		8 • 00	• 25500	4.08003	217A	
'-]	_	1.0		3.00	•77000	2.31000	217A	
15		0.4		3.50	•65000	9 10000	217A	
4		0.4		5.00	• 00625	• 12500	217A	
	CRYSTAL, JUARTZ	2.0	36	1.00	• 02000	00040	217A	

34.99174 FAILURES PER MILLION HOURS 36.00000 FAILURES PER MILLIAN HBURS 28578-1680 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FALUNE RATE EGUALS DESISH FAILURE RATE GRAL MOTGROLA, INC. FAILURE RATE DETERMINATION

I Total sensor

YEDEL RIT UNIT MODULE CLOCK PHASE CONTROL PRBJECT 3995-113

DATE APR 21, 71

TEMP 50. C

NET FOLD CAROL TANABOLD	ALC	SIRESO IN	FACTAR	FATI UPE RATE	MILLIAN ARS	1 X - 1 V	NOTES
	;					2000	
CAPACITUR, CER, CK	3.8.5		2.00	04900	1.21600	217A	
CAPACITUR, MICA, CM	0.4		15.00	.00071	•04590	217A	
S3 COIL, RF	5.0		8 • 60	• 22000	2 83800	2174	
DIBDE, SILICON, 0-1 WATT	1.0		3.50	•25500	•89250	217A	
INTEGRATED CIRCUIT, DISITAL	4.0		1.00	00004.	1 • 60000	217A	
INTEGRATED CINCUIT, LINEAR	15.0		1.00	00004•	4 • 80000	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION	28.0		10.00	00+00•	•11200	217A	
RESISTOR, FIXED METAL FILM	10.0		• 30	•17000	.51000	217A	
RESISTBH, WW VAR. LEAD SCREW ACT.	1.0		18.00	00960•	1.72800	RADC	
S. TRANSFURMER, MF	5.0		10.00	• 22000	3 30000	217A	
TRANSISTOR, SILICON APA, 0-1 MATT	1.0		8 • 00	•25500	2.04003	2174	
TO DODE, HOT CARRIER	4.0		3.50	•65000	9 • 10000	217A	
CAPACITOR, T C CER, CC	8.0		2.00	• 00625	• 25000	217A	
G CRYSTAL, QUARTZ	**	30	1.00	•05000	•08000	217A	

28,50932 FAILURES PER MILLION HOURS TOTAL FAILURE RATE EQUALS

MEAN TIME BETWEEN FAILURES EQUALS 35075.2422 HOURS

30.00000 FAILURES PER MILLIUN HOURS DESIGN FAILURE RATE GOAL

MOTGRBLA, INC. FAILURE RATE DETERMINATION

MODEL POSITIONING SET	
RTJ CABLE HARNESS	TERP 50. C
MADULE	
PRBJECT 3995-113	DATE APR 21, 171

COMPONENT DESCRIPTION	7 7 5	STRESS IN GIY PERCENT	FACTBR	BASIC FAILURE RAIE	FAILURES PER MILLION 145.	F.R. SBURCE	NOTES
THE STATE OF THE S	13.0		G: • 4	000000	2.885000	217A	
CONTRACTION OF LINE	2	ن ب	6.30	•18200	2.15.	217A	
SA CONNECTER, 15 PINS	3.0		6.00	.34300	1.85263	217A	
	1.5		6.00	1.22500	3+30750	217A	

10.82370 FAILURES PER MILLION HOURS	MEAN TIME BETWEEN FAILURES EQUALS 97811.9375 HBURS	12.00000 FAILURES PER MILLION HOURS
TOTAL FAILURE RATE EGUALS	YEAN TITE BETWEEN FAILURES	DESIGN FAILURE RATE GOAL

FAILURE RATE DETERMINATION MBTBRBLA, INC.

PR6JECT 3995-113

ACDU-DPU MODULE

MODEL POSITIONING SET

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AP 21, 171 DATE

NUTES F.K. SBURCE 217A 217A 217A 217A 217A 217A 217A 217A FAILURES PER MILLION ARS. • 06250 4.92000 1.44000 .21600 4 + 40000 •21450 •08200 2.00000 1.70280 •40800 2.04000 2.17600 FAILURE RATE 00004. 07900 00655 .0000 17000 .2000 .22000 40000 00400 .17000 22000 25500 BASIC FACTOR 15.00 10.00 8.60 1.00 5.00 10.00 1.00 1.00 10.00 • 30 STRESS IN PERCENT RESISTOR, FIXED CARBON COMPOSITION TRANSISTOR, SILICON APA, 0-1 MATT INTEGRATED CIRCUIT, DIGITAL INTEGRATED CIRCUIT, LINEAR RESISTOR, FIXED METAL FILM COMPONENT DESCRIPTION SLD TANT, CSR CAPACITUR, T C CER, CAPACITURA MICA, CM TRANSFORMER, RF COIL, AUDIB CAPACITOR CAPACITOR COIL, RF

19.66473 FAILURES PER MILLION HOURS TOTAL FAILURE RATE EQUALS

50852.4531 HBURS MEAN TIME BETWEEN FAILURES EQUALS

DESIGN FAILURE RATE GBAL

21.00000 FAILURES PER MILLION HOURS

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MOTOROLA, INC. FAILURE RATE DETERMINATION

MODEL POSITIONING SET 50. C 1日イド MODELE DRU PAR SUP PRBJECT 3995-113 DATE APR 21,171

	COMPONENT DESCRIPTION	7	OTY PERCENT	FACTBR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SBURCE	NUTES
	CAPACITHE. S. S. TANT. CO.	- 1					;	
		0		00.1	0001	7007	61/A	
	CAPACITUR, FUIL TANT, CL	2.0		8.00	• 03650	1.38403	217A	
	CBIL, AUDIS	1.0		10.00	• 20000	2 • 00000	217A	
	DIBDE, SILICBN, 0-1 AATT	15.0		3.50	• 25500	13 38750	2174	
	RELAY, HALF CAYSTAL CAN	1.0		50.00	•03310	•15500	217A	
*5	RESISTOR	19.0	30	10.00	00400	•07600	217A	
24	RESISTOR, FIXED METAL FILM	50		• 30	.17000	•00102	217A	
	TRANSFORMER, POWER	1.0		10.00	• 22000	2 - 2000.0	2174	
	THANSISTUR, SILICON VPV, C-1 AATT	0.4		8 • 00	. 25500	8 16000	217A	
	SILICON APA	1.0		8.00	•51000	4 • 080.0	217A	
53	TRANSISTUR, SILICON OND, 0-1 WATT	3.0		8.00	•67000	4 - 824 03	2174	
F	ZENER DIBDE, 0-1 MATT	3.0		3.00	•77000	6.93000	2174	
'-]	CAPACITOR, CER, CK	3.0		5.00	04900	• 09600	217A	
158	CONNECTOR, 15 PINS	ល		00.9	·34300	1.02900	2174	
3				•				

44.42442 FAILURES PER MILLION HOURS 46.00000 FAILURES PER MILLION HOURS 22510-1367 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FAILURE RATE EQUALS JESISY FAILURE RATE GOAL

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		STRESS IN A	¥	BASIC	FAILURES PER	F. R.
COMPONENT DESCRIPTION	OTY	PERCENT	FACTOR	FAILURE RATE	MILLION HRS.	SBURCE
CAPACITUM, CEM, CA	15.0		5.00	0.000	.48303	217A
S. CONNECTOR, 36 PINS	1:0	30	00.9	1.22500	2.20500	217A
Sa INTEGRATED CIRCUIT, DIGITAL	0.44		1.00	00000	5.28000	217A
SA RESISTOR, FIXED CARBON COMPOSITION	2.0		10.00	00400	•05000	2174

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FAILURES	
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MEAN TIME BETWEEN FAILURES EGUALS 125235.0000 HBURS

DESIGN FAILURE RATE GOAL 13.000

13.00000 FAILURES PER MILLION HOURS

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FAILURE RATE DETERMINATION MBTBRBLA, INC.

		F.K. SBURGE
MODEL POSITIONING SET		FAILURES PER MILLIBY 485.
48DEL 28S		BASIC FAILURE RATE
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MODULE DPU MSG BUTPUT CTR.	<u>я</u>	STRESS IN K GIY PERCENT FACTOR
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PRBJECT 3995-113	DATE APT 210171	COMPONENT DESCRIPTION
à	D	COMPONENT

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. 5120) 2.20503 5.64000

.00640 .40000 .00400

6.00 10.00 10.00

16.0 1.0 47.0

SA CONNECTURA 36 PINS SA INTEGRATED CINCUITA DISITAL SA RESISTORA FIXED CARBON CUMPOSITION

Contact treat tree chair tree contact	STICKED THE HILLION HOUND	MEAN TIME DETWEEN FAILURES EQUALS 118635-1875 HOURS	13.00000 FAILURES PER MILLION HOURS
TETAL SIGN DATE COLLAR O	ביים איניים ארוביים איניים איניים	YEAN TINE DETWEEN FAILURES	DESIGN FAILURE RATE GOAL

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COMPONENT DESCRIPTION) TO	STRESS IN K GTY PERCENT FACTOR	FACTBR	BASIC FAILURE RATE	FAILURES PER MILLIBN HAS.	F.R. Source	NOTES
CAPACITOR, CER, CK	15.0	30	5.00	04900	.48000	217A	
S3 CONVECTOR, 36 PINS	1.0	30	00.9	1.22500	2.20500	217A	
SA INTEGRATED CINCUIT, JISITAL	46.0	30	1.00	• 40000	5.52000	217A	
SA RESISTOR, FIXED CARBON COMPOSITION	0.9	30	10.00	•00400	•05+00	217A	

TOTAL FAILURE RATE EQUALS

8.22899 FAILURES PER MILLION HOURS

MEAN TIME BETWEEN FAILURES EGUALS 121521.6250 HBURS

DESIGN FAILURE RATE GOAL 13.000

13.00000 FAILURES PER MILLIUN HOURS

MBTBRBLA, INC. FAILURE RATE DETERMINATION

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MEDEL POSITIONING SET	
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)ÈC9)ER	50.
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OPJ	
MGDULE	
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F.K. SBUACE	217A 217A 217A 217A 217A
FAILURES PER MILLIBY HAS.	5. 80 5. 5. 5. 5. 5. 5. 5. 5. 5. 5. 5. 5. 5.
BASIC FAILURE HAIE	
FACT9R	5.00 6.00 10.00 1.000
STRESS IN A GTY PERCENT FACTOR	၁၀၁၁၁ ოოოოო
¥15	4 4 4 0 H
COMPONENT DESCRIPTION	CAPACITER, CEM, CA S3 CONNECTEM, 36 PINS S3 INTEGRATED CINCUIT, DISITAL S4 RESISTOR, FIXED CARBON COMPOSITION CAPACITON, SLD TANT, CSR

8.02997 FAILURES PER MILLIBN HBURS	4375 HBURS	13.00000 FAILURES PER MILLIUN HBURS
8. C2997 FAI	EQUALS 124533.	13.00000 FAIL
TOTAL FALLUNE RATE EGUALS	MEAN IIME BLIWEEN FAILURES EQUALS 124533.4375 HBURS	DESIGN FAILURE RATE GOAL

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Accounts of Contraction of Contractions of Con		MEDEL POSITIONING SET	
A company of the comp		165	u
A designation of	7611	J.	5C•
	MBTBRBLA, INC.	MBDULE CABLE HARNESS-JPU	TEMP
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	FAILU	48DULE	
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		STRESS IN		BASIC	FAILURES PER	F.K.	
COMPONENT DESCRIPTION	OTY	OTY PERCENT FACTOR		FAILURE RATE	MILLIBN HRS.	SOURCE	NOTES
AND TORNAL	2.0		4.00	00070•	• 32000	217A	
15	S		6.00	•34300	1 • 02900	217A	
SA CONNECTOR, 36 PINS	7.0	30	00.9	1.22500	15.43501	217A	
CONNECTOR, 20 PINS	• •		00.9	• 48600	1.45800	217A	

LLIBN HBUKS		TON HOURS
PER MI	HBURS	PER MIL
18.24200 FAILURES PER MILLION HOURS	54818.5352 HBURS	SAUGE TATILISES PER MILLION HOURS
18.5	EQUALS	27.000
	FAILURES	1800
URE RATE	BETWEEN	7 1.0E DAT
TOTAL FAILURE RATE EQUALS	MEAN TIME BETWEEN FAILURES EQUALS	DECTON FATITUDE BATE GRAIN
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METOROLA, INC. FAILUNE RATE DETERMINATION

PS SET	
AIRBBANE	
MEDEL	
	50.0
YENDRY PAR SUP	TEMP
MEDULE	
CT 3995-113	DATE APR 21,171
PREJECT	DATE

		STRESS IN		BASIC	FAILURES PER	2	
COMPONENT DESCRIPTION	TTC	PERCENT	FACTOR	FAILURE RATE	MILLION 435.	SBURCE	NOTES
CAPACITORS SLU TANTA CSR	ó• Č		1.50	17000	•1020	217A	
CAPACITERS FULL TANTS CL	₽• S		8.00	03650	1 • 38400	217A	
COIL» AUDIO	1.0		10.00	.20000	2.00003	217A	
DIGDE, SILICON, 0-1 MATT	15.0		3.50	• 25500	13+38750	217A	
RELAY, HALF CHYSTAL CAY	1.0		50.00	.00310	•15500	217A	
S4 RESISTER, FIXED CARBON COMPOSITION	19.0		10.00	00400	0.970	217A	
	2.0		• 30	•17000	•00102	217A	
TRANSFORMER, PONER	1.0		10.00	• 22000	2.20003	217A	
マルス	0 • ‡		8.00	•25500	8.16500	217A	
TRANSISTER, SILICEN VPN, 1-50 HATT	1.6		30.0	.51600	4.08000	217A	
I TRANSISTER, SILICEN PNP. 0-1 WATT	3.0		8.00	.67030	16.07959	217A	
S ZENER DIBDE, 0-1 "ATT	3.0		3.00	•77000	6.93000	217A	
	3.0		2.00	049000	c0960·	217A	
CONVECTOR, 15 PINS	• S	36	00.9	•34300	1.02900	217A	

55.68042 FAILURES PER MILLION HOURS	8 HBURS	60-66660 FAILURES PER MILITAN HBURS
5.68042 FAILUR	S 17959-6328 HBURS	OCCOO FAILURE
	FAN TI 1E BETWEEN FAILURES EQUALS	
TETAL FAILURE RATE EQUALS	E BETWEEN FI	JESISS FAILURE RATE GBAL
TSTAL FA	FAN TI	JESION F

FAILURE RATE DETERMINATION MOTOROLA, INC.

AIRBORNE MEMBRY MEDULE PRBJECT 3995-113

MODEL AIRBORNE POS SET

APR 21, 171 DATE

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NOTES SOURCE 2174 217A 217A 217A 217A 217A 217A 2174 F. R. 2174 2174 2174 FAILURES PER MILLION HRS. 4.69200 .28900 13.38750 16.39999 16.39999 6.64653 • 49922 •16003 11.98800 8.56801 4.62000 13,12201 FAILURE RATE 17000 .22200 •48600 •25500 000004. 00000 •17000 1.05500 •25500 00027. 04900 •00005 BASIC FACTOR 9.00 1.00 1.00 1.30 00.9 3.50 3.00 1.00 8.00 3.00 5.00 STRESS IN PERCENT 5.0 41.0 0.6 15.0 50.0 41.0 21.0 14.0 5.0 31 201.0 TAANSISTOR, SILICON VPV, 0-1 INTEGRATED CIRCUIT, DIGITAL INTEGRATED CIRCUIT, LINEAR RESISTOR, FIXED METAL FILM RESISTOR, FIXED WIRE MOUND COMPONENT DESCRIPTION DIBDE, SILICON, 0-1 HATT CAPACITUR, SLD TANT, CSR ZENER DIBDE, 0-1 WATT 10 PINS CONNECTOR, 20 PINS CER, CK CORES, FERRITE CORES, FERRITE CONNECTOR CAPACITURA

53

53

F-165

98.37216 FAILURES PER MILLION HOURS TOTAL FAILURE RATE EGUALS

1.59998

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0.666 66

10165.4766 HBURS MEAN TIME BETWEEN FAILURES EQUALS

110.00000 FAILURES PER MILLION HOURS DESIGN FAILURE RATE GOAL MUTSKULA, INC. FAILUKE KATE DETERMINATION

FILTER , AIRBORNE MEDOLE PRBJECT 3995-113

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MODEL POSITION SETAMIR

DATE APR 21,171

FAILURES PER MILLIBN HRS. STRESS IN K BASIC GTY PERCENT FACTOR FAILURE RATE

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•17503

F.A. SBURCE

NUTES

CAPACITURA VAR ALA, CT

COMPUNENT DESCRIPTION

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TOTAL FAILURE RATE EGUALS

.17500 FAILURES PER MILLIBN HBURS

MEAN TIME BETWEEN FAILURES EQUALS 5714285.0000 HBURS

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PRBJECT 3995-113 MODULE CONTROL & MOVITOR

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DATE AP4 21,171

FAILURES PER MILLION HRS. BASIC FAILURE RATE FACTOR GTY PERCENT COMPONENT DESCRIPTION

NUTES

F.R. SBURCE

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6.24363 1.09200 7.35000 9.45001

S. COIL, AF
CONNECTUR, 8 PINS
CONNECTUR, 36 PINS
S. SWITCH, 18GGLE BR PUSHBUTTON

11.0 30 8.60 .22000 1.0 30 6.00 1.22500 7.0 30 18.00 .25000 24-13559 FAILURES PER MILLION HOURS TOTAL FAILURE RATE EQUALS

MEAN TIME BETWEEN FAILURES EQUALS 41432-5898 HBURS

25.00000 FAILURES PER MILLION HOURS

DESIGN FAILURE RATE GBAL

MOTORDA INC. FAILURE RATE DETERMINATION

PRBJECT 3995-113 MBJJLE		RUBIDIOM FREG	EG STO	MADEL AIR	AIRBURNE PES SET		
DATE APR 21,171		TEM	P 50	U			
COMPONENT DESCRIPTION	E T	STRESS IN PERCENT	FACTBR	BASIC FAILURE RAIE	FAILURES PER MILLION HAS.	F.A. SBURCE	NUTES
ALUY EI	•		• 60	•23500	130	7	
	0.+	36	•	· 52300	9	217A	
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TBK, MYL	ů	<u>ع</u> ر	•	•00185	•1625J	1	
	ů	30	•	•17000	1.39400	7	
CAPACITER, VAR	•	30	•	• 03500	•10500	1	
	•	3°	•	• 22000	•	7	
CONNECTER	•	30	•	303×C•	•		
	•	ع ع	•	•1820C	•	1	
	•	30	•	• 48600	•	-	
CRYSTAL, GUARTZ	•	30	•	0	00090	7	
DIBDE, GERMANIUM, 0+1 WATT	ŝ	<u>ာ</u>	•	2.55000	7	7	
0-1	•	3C	•	• 25500	30.34499	~	
DIBDE, SILICON, 1-50 WATT	8.0	30	12.00	• 43000		1	
FILTER, FEED THRU	•	၁၉	•	•05400	• 05400	17	
(ě	၁၉ (•	•10000	• 30000	1	
	16.0	30	•	00004.	00004.9	17	
INTEGRATED CINCUIT, LINEAR	ċ	30	•	00004.	00000 • 4	17	
	•	၁၉	1	• 50000	• 50000	1	
KELAY, HA		သူ	•	•00310		17	
RESISTORS FIXED	S.	<u>၁</u> ၉	ċ	• 00400	1 • 18000	17	
•	•	30	•	•17000	•02397	17	
RESISTORS FIXED SIRE MOUND	Š	n O	3.00	1.05	6.33000	17	
NON-AR VAR. L. S.	•	30	9	•30	8	17	
RESISTOR, NE VAR.	ີດ	၁၉	18.00	00960•	8 • 640	RADC	
SE SEITCH, TOGGLE BY PUSHBUTTON	•	3C	8.0	• 25000	•6000	17	
	•	30		000	•600	17	
	-	30		S	2.20000	-	
TRANSFORMER, AF	•	30	0.0	20	•0000	2174	

217A	2174	217A	217A	217A	217A	217A	217A	217A
16.07999	33.60001	37.94460	40 • 79999	17-68800	21 • 4 4 0 0 0	3.57000	18.48000	2.31000
00029•	2.10000	•25500	•51000	•67000	1.34000	•25500	.77000	•77000
8.00	8.00	8.30	8.00	8.00	6.30	3.50	3.00	3.00
		و عر						
		62.0				*	8	
TRANSISTUR, FIELD EFFECT	GERMANIUM D	SILICON	SILICEN APA	SILICON PNP	SILICEN PNP			E. 1-50 WATT
TRANSISTUR,	TRANSISTOR	S. TRANSISTUR,	TRANSISTOR,	SA TRANSISTUR	TRANSISTUR,	VARICAP	LENER DIBDE	ZENER DIBDE

486.23047 FAILURES PER MILLION HOURS 25.00000 FAILURES PER MILLION HOURS 2056.6377 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FALLURE RATE EQUALS DESIGN FAILURE RATE GOAL

METERCLA, 17.0.	RATE CETERAINATION
	FAILURE

		F.h. SBURCE
MADEL LAPDS SYSTEM		FALLURES PER MILLIBN 485.
MADEL LAP	U	BASIC FAILURE RAIE
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BUTSIDE CABLES	15.	STRESS IN PERCENT
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PREJECT 3995-113	DATE AP4 21,171	COMPONENT DESCRIPTION

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CONNECTORS RF CONNECTORS

LIBN HBURS	
2.34400 FALLURES PER MILLION HOURS	426621.3125 HBURS
2.344CO F	EGUALS 4266
TOTAL FAILUNE RATE EGUALS	YEAN TITE BETWEEN FAILURES EGUALS
TOTAL FAI.	7EAN TI 1E

MOTOROLA, INC. FAILURE RATE DETERMINATION

PRBJECT 3995-113 TOTAL OF ALL MODULES

DATE APR 21, 71

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TEMP 50. C

1258-64673 FAILURES PER MILLION HOURS TOTAL FAILURE RATE EQUALS

MEAN TIME BETWEEN FAILURES EQUALS 794-5039 HBURS

APPENDIX F-4.6

RELIABILITY TEST CONDITION

RELIABILITY PREDICTION DATA SHEETS

REFERENCE POSITION SET AN/ASQ-148

ENVIRONMENT: GROUND

TEMPERATURE: +25°C

STRESS LEVELS: 30% (ASSUMED) EXCEPT

RUBIDUM STANDARD STRESSES

10% (ASSUMED)

MOTOROLA, INC. FAILURE RATE DETERMINATION

25. C MADULE POWER CONVERTER TEMP PRBJECT 3995-113

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COMPONENT DESCRIPTION	OTY.	STRESS IN	FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITUM, CEN, CK	3.0	30	1.00	• 00512	•01537	217A	
CAPACITUR, SLU TANI, CSR	9.0	30	1.00	•11000	00660·	217A	
CAPACITOR, FOIL TANT, CL	2.0	30	1.00	00990•	• 13200	217A	
COIL, RF	8.0	30	1.00	• 22000	1.76000	217A	
	8.0	30	1.50	• 25500	3 06003	217A	
S	1.0	30	1.00	• 43000	• +3000	217A	
u	0.6	30	1.00	•01000	00060	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION	8.0	30	00.9	•00320	•01680	217A	
RESISTOR, FIXED METAL FILM	4.0	30	•03	•12000	•01440	217A	
TRANSFORMER	1.0	30	1.50	• 22000	•33000	217A	
-	1.0	30	1.50	• 25500	• 38250	217A	
TRANSISTOR, SILICON NPN, 1-50 WATT	1.0	30	1.00	•51000	•51000	217A	
	5.0	30	1.50	•67000	©•01000	217A	
ZENER DIBDE, 0-1 MATT	1.0	30	1.00	•77000	•77000	217A	
CONNECTOR, 8 PINS	7.0	30	1.10	•18200	• 20020	17	

9.82027 FAILURES PER MILLIGN HOURS MEAN TIME BETWEEN FAILURES EQUALS 101830-1875 HOURS TOTAL FAILURE RATE EQUALS

DESIGN FAILURE RATE GOAL

44.00000 FAILURES PER MILLISN MOURS

MOTORDAY INC. FAILURE RATE DETERMINATION

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T 3995-113	APR 21,171
PRBJECT	DATE

COMPONENT DESCRIPTION	Y L	STRESS IN PERCENT	FACTBR	BASIC FAILJRE RATE	FAILURES PER MILLION HRS.	F.R. SBURCE	NOTES
XO SHIP SHIP SHIP	16	(1.00		7.770	47.40	
		2		11000	100	W/13	
CAPACITUR, MICA, CM	3.0	<u>ع</u>	1 • + 0	• 00032	• 00145	217A	
COIL, RF	1.0	30	1.60	• 22000	• 22300	217A	
CONNECTOR, RF	3.5	30	1.10	• 04000	•15400	217A	
CONNECTOR, 15 PINS	• 5	36	1.10	•34300	•188 ₅ 5	217A	
INTEGRATED CIRCUIT, LINEAR	5:0	30	1.00	00004.	2 • 00000	217A	
RELAY, HALF CRYSTAL CAL	1.0	30	2.50	•00310	• 00775	217A	
	19.0	30	6.00	•00320	•03990	217A	
		30	•10	33 45 458	• 33425	217A	
DIBUE, HUT CARRIER	0 • •	3 3	1.50	•65000	3+90000	217A	
	200	3C	1.50	• 22000	•66000	217A	
CAPACITBE, VAR AIR, CT	2.5	၁၉	1.00	•02220	•04200	217A	
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7.62787 FAILURES PER MILLION HOURS 19.00000 FAILURES PER MILLIUN HOURS MEAN TIME BETWEEN FAILURES EQUALS 131098-1875 HOURS TOTAL FAILURE RATE EGUALS DESIGN FAILURE RATE GOAL

NOTE1: FACTOR OF 0.1 APPLIED TO FAILURE RATE DUE TO NO FIELD ADJUSTMENTS

MOTOREALE INC. FAILURE RATE DETERMINATION

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277-177	DATE APR 21,171

COMPONENT DESCRIPTION	SYTO	STRESS IN PERCENT	FACTOR	BASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SOURCE	NOTES
CAPACITOR, CER, CK	61.0	ာဗ	1.00	•00512	.31262	2174	
COIL, RF	24.0	30	1.00	• 22000	5.28000	217A	
-	1.5	30	1.10	90900	00990	217A	
DIBDE, HOT CARRIER	•	30	1.50	• 65000	2.92500	217A	
DIBDE, SILICON, 0-1 MATT	_	30	1.50	• 25500	3.06000	217A	
4 RESISTOR, FIXED CARBON COMPOSITION	33.0	30	9.00	• 00320	• 06930	217A	
TRANSFORMER, RF	10.0	90	1.50	• 22000	3+30000	217A	
TRANSISTUR, FIELD EFFECT	0.6	30	1.50	•67000	9.04500	2174	
TRANSISTUR, SILICON VPV, 0-1 WATT	1.0	30	1.50	• 25500	•38250	2174	
TRANSISTOR, SILICON VPN, 1-50 WATT	9.0	30	1.00	.51000	4+59000	217A	
CONNECTOR, 36 PINS	S	30	1.10	1.22500	•67375	2174	

HOURS
MILLION HOURS
PER
29.70415 FAILURES
.70415
29
EGUALS
RATE E
TOTAL FAILURE
TOTAL

33665.3320 HBURS MEAN TIME BETWEEN FAILURES EQUALS

95.00000 FAILURES PER MILLION HOURS DESIGN FAILURE RATE GOAL

FAILURE RATE DETERMINATION MATGRULA, INC.

C 25. XMTR MBDULATBR TEMP 発している PRBJECT 3995-113

MEDEL AZT UNIT

APR 21,171 DATE

Vares F.R. SOURCE 217A 217A 217A 217A 2174 217A 217A 217A 217A 217A FAILURES PER MILLION HRS. • 03075 • 022C0 1.32000 00044. 7 • 80000 3.82500 •80000 •02325 •06300 3.82500 •77000 FAILURE RATE •2550L .11000 .22000 •6500C 00004. .00310 • 60356 • 2200c •255cc 20024 •C0512 BASIC FACTBR 00000 1.00 1.500 2.50 STRESS IN STRESS IN PERCENT 30.0 10.0 RESISTOR, FIXED CARBON COMPOSITION TRANSISTUR, SILICON APA, 0-1 AATT DIODE, HOT CARRIER DIODE, SILICON, 0-1 MATT INTEGRATED CIRCUIT, LINEAR RELAY, HALF CRYSTAL CAY COMPONENT DESCRIPTION CAPACITER, SLD TANT, CSR ZENER DIBDE, 0-1 WATT CAPACITUR, CER, CK TRANSFORMER, MF COIL, KF

18.91898 FAILURES PER MILLIGN HOURS TOTAL FAILURE RATE EQUALS

52856.9805 HBURS MEAN TIME BETWEEN FAILURES EQUALS

52.00000 FAILURES PER MILLIUN HOURS DESIGN FAILURE RATE GOAL

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MOTOROLA, INC. FAILUKE RATE DETERMINATION

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PRBJECT 3995-113

DATE APR 21,171

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TEMP

		STRESS IN		BASIC	FAILURES PER	×.	
COMPONENT DESCRIPTION	YT0	OTY PERCENT	FACTBR	FAILURE RATE	MILLIBN HRS.	SBURCE	VOTES
CAPACITOR, CEM, CK	22.0		1.00	51500	11275	47.10	
) 				71144	() 1 1	
CAPACITUR, MICA, CM	16.0		1.40	• 00052	+01159	217A	
COIL, RF	8.0		1.00	•22000	1.76000	217A	
DIBDE, HOT CARRIER	12.0		1.50	•65000	11.70000	217A	
DIBDE, SILICON, 0-1 MATT	5.0		1.50	• 25500	1.91250	217A	
INTEGRATED CIRCUIT, LINEAR	2.0		1.00	• 40000	€80000	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION			00.9	•00320	•11970	217A	
TRANSISTUR, SILICON NPV. 0-1 MATT			1.50	• 25500	2+29500	217A	
TRANSISTUR, SILICON PNP, 0-1 MATT	8.0		1.50	.67000	2.01000	217A	
TRANSFORMER, RF	0.4	30	1.50	.22000	1.32000	217A	
HESISTOR VARIABLE, 10-TURN	1.0		1.00	1.01500	1.01500	SM-188	

23.05650 FAILURES PER MILLION HOURS TOTAL FAILURE RATE EQUALS

43371-7109 HBURS MEAN TIME BETWEEN FAILURES EQUALS

66.00000 FAILURES PER MILLIUN HOURS DESIGN FAILURE RATE GOAL

MOTOREATE DETERMINATION

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MADEL A/T U	
	25. C
(S (SEC)	TEMP
FREG SYN 2 (REC)	
MBJOLE	
PRBJECT 3995-113	APR 21,171
PRBJEC	DATE

MODEL AZT UNIT	
	U
	25. C
FREG SAN 2 (REC)	TEMP
MBJOLE	
ECT 3995-113	APR 21, 171

		STRESS IN		BASIC	FAILURES PER	F . K.	
COMPONENT DESCRIPTION	★ L®	PERCENT	FACTBR	FAILURE RAIE	MILLIBN ARS.	SOURCE	NOTES
CAPACITUM CEM, CK	78.		1.00	.00518	11275	217A	
CAPACITOR, MICA, CM	16.6		1 • +0	•00052	• 01159	217A	
C01L, RF	9.0		1.00	• 22000	1.76000	2174	
DIBUE, HUT CARRIER	12.0		1.50	•65000	11.70000	217A	
DIBDE, SILICBN, U-1 AATT	5. C		1.50	• 25500	1.9125.0	2174	
INTEGRATED CIRCUIT, LINEAR	3.0		1.00	00004.	• 80000	217A	
SA RESISTOR, FIXED CARBON CUMPOSITION	57.0		00.9	•00320	.11970	217A	
TRANSISTOR, SILICON YPV, D-1 AATT	0.9	30	1.50	• 25500	2.29500	217A	
TRANSISTER, SILICEN PUR, U-1 NATT	20.0		1 • 50	00029.	2.01000	217A	
	0 • 4		1.50	• 22000	1 • 32000	217A	
	1.0	ე <u>ც</u>	1.00	1.01500	1.01503	SM-188	
2 CONNECTOR RF	3.0		1.10	000+0•	•13200	217A	
COLNECTOR, 15 PINS	•		1.10	.34300	•18865	217A	

TOTAL FALLUNE RATE EGUALS	23.37714 FAILURES PER MILLION HOURS	ILLISN HBURS
MEAN TI1E BETWEEN FAILURES EQUALS 42776.8359 HOURS	EQUALS 42776.8359 HBURS	
DESIGN FAILURE RATE GRAL	RAIL MET LITE GREE REFERENCE AND COUNTY AND	

MBTBRBLA, INC. FALURE RATE DETERMINATION

MODULE CARRIER 19/VCB PRBJECT 3995-113

DATE APR 21,171

25. C TEMP

MEDEL AZT UNIT

COMPONENT DESCRIPTION	¥T0	STRESS IN	FACTBR	BASIC FAILURE RAFE	FAILURES PER MILLION ARS.	F.A. SBUACE	NUTES
	•	၁	1.00	• 32250	4	17	
	72.0	<u>ع</u>	1.00	•00512	•36900	17	
\rightarrow	+	3 0		•00052	•01014	17	
	0.9	30	1.00	•22000	1 • 32000	17	
CY.	•	эc	1.10	00040	•13200	17	
	·.	30		•34300	886	17	
SILI		30	1.50	•25500	vı	17	
TED CINCUIT,	3.0	30	1.00	00004.	000	17	
(.)	19•0	၁၉	1.00	• 4 3030	v	17	
FIXED	80.0	3 <u>0</u>	6.03	•00350	1680	17	
	7.	30	•03	(U	972	17	
RESISTBR. AK	•	30	0	•07100		9	
TRANSISTUR, SILIC	2.0	30	1.5	ເກ	.9125	17	
Q		30	1.00	•77000	2.31000	217A	
Т	•	90 8	5	R)	•	17	
Σ	S. O.	<u>၁</u> ၉	S	• 22000	• 66000	17	
DART	•	၁၉	0	3	00090	17	
T C CER, CC		၁၉	0	O	110	17	
VAR GLASS	•	30	1.00	247	47	17	
CAPACITUR, VAR C	•	30	1.00	• 02550	• 02250	17	
SA RESISTOR, FIXED METAL FILM		ЭC	•03	.12000	+00000	17	

25.17724 FAILURES PER MILLIBN HBURS TOTAL FAILURE HATE EGUALS

38793.9141 HBURS MEAN TIME BETWEEN FAILURES EQUALS

DESIGN FAILURE RATE GOAL

54.00000 FAILURES PER MILLIUN HOURS

MOTORDIA, INC. FAILURE RATE DETERMINATION

CODE DETECTOR . MODEL 4/1 UNIT	
MEDULE CODE	
PREJECT 3995-113	1415 404 31 1171

		STRESS IN		CASIC	FAILURES PER	2	
COMPUBLENT DESCRIPTION	GTY	GTY PERCENT	FACT98	FAILURE RATE	MILLIBY ARS.	SOURCE	ADTES
CAPACITEM, CEM, CK	46.0		1.00	•00512	•23575	217A	
CAPACITUR, MICA, CM	0.4	30	0+•1	• 00052	• 60250	217A	
CONNECTUR, 15 PINS	S •		1.10	•34300	• 18865	217A	
DIBDE, SILICON, 0-1 AATT	7.0		1.50	• 25500	2.67753	217A	
INTEGRATED CINCUIT, DISITAL	3.0		1.00	30004.	1.20000	217A	
INTEGRATED CINCUIT, LINEAR	19.0		1.00	000004.	7 - 60000	217A	
RESISTOR, FIXED METAL FILM	28.0		• 03	•12000	•10060	217A	
RESISTOR, NW VAK. LEAD SCREW ACT.	1.0		18.30	•07100	1.27800	RADC	
TRANSISTUR, SILICUN VPV. 0-1 AATT	1.0		1.50	• 25500	• 38253	217A	

N HBURS		HOURS
MILLIO	S	HILLION
S PER	E S	PER
13.66609 FAILURES PER MILLION HOURS	MEAN TIME BETWEEN FAILURES EQUALS 73173.7500 HBURS	16.00000 FAILURES PER MILLION HOURS
• 66609	73	00000
13	EGUALS	16.
TOTAL FAILURE RATE EQUALS	VILURES	GBAL
ATE 8	EN FI	RATE
URE R	BETWE	LURE
FAIL	11 1E	FAI
TETAL	MEAN	DESIGN FAILURE RATE GOAL

MOTORALA INC. FAILURE RATE DETERMINATION

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MODEL A/T UNIT	
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CACU (DIGITAL)	ተ ም
CACU	
MODULE	
A8JECT 3995-113	DATE AP4 211171
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		SIRESO IN	1	3A51C	TALLOADU TER		
COMPONENT DESCRIPTION	YT0	OTY PERCENT	FACTOR	FAILURE RAIE	MILLION ARS.	SBURCE	DR
CAPACITOM, CEM, CA	30.0		1.30	•03518	•15375	217A	
INTEGRATED CINCUITA DISITAL	71.0		1.00	30004.	28 • 39999	217A	
RELAY, HALF CHYSTAL CAN	1.0		2 - 50	.00310	• 00775	217A	
S4 RESISTOR, FIXED CARBON COMPOSITION	54.0		6.00	•03350	•11340	217A	
CAPACITURA MICAS CM	0.9		1.40	•00052	CS +00 ·	217A	
COIL, AF	3.0		1.00	• 22000	• 66000	217A	
CONNECTOR, RF	0.9		1.10	00070•	.26403	217A	
CONNECTOR, 36 PINS	ពេ	30	1 - 10	1.22500	•67375	217A	

TES

30.27692 FAILURES PER MILLION HOURS 20.00000 FAILURES PER MILLION HOURS 33025.4609 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FAILURE RATE EQUALS DESIGN FAILURE RATE GBAL MOTOROLA, INC. FAILURE RATE DETERMINATION

CACU (DIGITAL) MODULE PR9JECT 3995-113

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NOTES

DATE APR 21,171

TEMP

25. C

COMPONENT DESCRIPTION	S	STRESS IN A PERCENT FACTOR	FACTBR	SASIC FAILURE RATE	FAILURES PER MILLION HRS.	F.R. SBURCE
CAPACITUM, CEN, CA	30.08	ტ ე	1.33	• 0.0512	•15375	217A
S. INTEGRATED CINCUIT, DISITAL	71.0	9	1.00	00004.	8+52000	217A
RELAY, HALF CRYSTAL CAN	1.0	30	2.50	•00310	• 00775	217A
S. RESISTER, FIXED CARBON COMPOSITION	24.0	30	00.9	•00320	•11340	217A
	0.9	30	1.40	• 00052	• 00435	217A
בפורי אל	3.0	Эċ.	1.00	• 22000	•66000	217A
CONNECTOR, RF	0.9	30	1.10	•04000	•26400	217A
CRANECTOR, 36 PINS	េះ	30	1.10	1.22500	•67375	2174
F-18						

10.39693 FAILURES PER MILLIBN HOURS TOTAL FAILUNE RATE EGUALS

96182.2500 HBURS MEAN TIME BETWEEN FAILURES EQUALS

DESIGN FAILURE RATE GOAL

20.00000 FAILURES PER MILLIUN HOURS

MOTORGIA, INC. FAILURE RATE DETERMINATION

MODEL AZT UNIT 25. € CLECK IG DETECTER TEMP MEDULE PREJECT 3995-113 DATE AP4 21, 171

		RES		BASIC	ATLURES P	7	
COMPONENT DESCRIPTION	GTY	PERCENT	FACTBR	FAILURE MATE	A. V.	SHURCE	VOTES
CAPACITERS VAR AIRS CT	1.0	30	1.00	• 02850	• 02250	217A	
CAPACITUM, CEM, CK	36.0	30	1.00	-3051Z	.18450	17	
CAPACITER, MICA, CM	10.0		1.40	• 00052	• 00724	17	
COIL, AF			1.00	• 22000	A.	17	
CBNZECTOX AF	3•6		1.10	000+0•	• 132 ₀ 3	17	
CONNECTED 15 PINS	៤		1.10	·34300	20	17	
DIBUE, SILICON, 0-1 MATT	200		1.50	• 25500	•76500	2174	
INTEGRATED	12.0	30	1.00	00004.	4.80000	217A	
S. RESISTOR, FIXED CARBON COMPOSITION	00		6.00	•00350	•10080	17	
RESISTOR'S FIXED METAL FILM	13.0		• 03	12000	.04683	17	
RESISTBR, AW VAR. LEAD SCHEW ACT.	1.0		18.00	.07100	1.27800	RADC	
	0.9		1.50	•22000	1.98000	17	
TRANSISTOR, SILICON NPV. 0+1 AATT	2.0		1.50	• 25500	•76500	17	
	1.0		1.00	.77000	•77000	17	
DIODE, HOT CARRIER	0.4		1.50	•65000	3+90000	17	
CAPACITOR, T C CER, CC	*		1.00	• 00275	•01100	17	
CRYSTAL, GUARTZ	2.5		1.00	• 05000	00000	17	

16.31146 FAILURES PER MILLION HOURS 61306.5781 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FAILUNE RATE EGJALS

DESIGN FAILURE RATE GOAL

36.00000 FAILURES PER MILLIAN HBURS

FAILURE RATE DETERMINATION MOTSRBLA, INC.

CL9CK PHASE CONTROL MODULE

SBURCE FAILURES PER MILLIBN ARS. •19475 MADEL AVT UNIT FAILURE RAIE 505512 U 25 FACTOR TEMP STRESS IN PERCENT 38.0 . PRBJECT 3995-113 AP4 21,171 COMPONENT DESCRIPTION DATE

NUTES

217A

217A 217A 2174 2174 2174

1.27800 .00290 1.10000 1 • 60000 •05880 •03600 1.65000 • 38250 • 38250 4 - 80000 3.90000 • 02200 00080 00004. .22030 25500 00000 .00320 .12000 .22000 -00052 07130 .25500 65000 00275 32000 C+ . 1 1.50 009-1 1.00 1.00 • 03 1.00 6.30 1.00 18.00 50 1.0 4.0 12.0 28.0 10.0 1.0 0.0 ** 1:0 RESISTOR, FIXED CARBON COMPOSITION RESISTOR, FIXED METAL FILM TRANSISTUR, SILICUN NPV, 0-1 AATT DIODE, HOT CARRIER CAPACITON, T C CER, CC RESISTOR, AM VAK. LEAD SCREN ACT. DIBDE, SILICBN, 0-1 MATT
INTEGRATED CINCUIT, DISITAL
INTEGRATED CINCUIT, LINEAR CAPACITON, MICA, CM CAPACITUM, CER, CK TANSFORMER, KF CRYSTAL, GUARTZ Š F-184

15.48744 FAILURES PER MILLION HOURS 64568.4453 HBURS MEAN TIME BETWEEN FAILURES EQUALS BTAL FAILURE RATE EGUALS

DESIGN FAILURE RATE GBAL

30.00000 FAILURES PER MILLIAN HBURS

MOTORSLA, IZC.	FAILURE RATE DETERMINATION

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RTJ CABLE HARNESS	TEMP
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3995-113	171
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PK8.	DATE

POSITIONING SET

COMPONENT DESCRIPTION	S	STRESS IN 4 OTY PERCENT FACTOR	FACT9R	BASIC FAILJRE HAIE	FAILURES PER MILLIBY HAS.	F.K. SBURGE	VOTES
CONNECTOR, RF	18.0	ე ე	1 • 10	000+0•	•79203	217A	
CONVECTOR 8 PINS	2.0	30	1.10	.18200	7+00+•	217A	
CONVECTOR, 15 PINS	3.0	30	1.10	• 34300	1.13190	217A	
CONNECTOR, 36 PINS	1.5	၁၉	1.10	1.22500	2.02125	217A	

4.34555 FAILURES PER MILLION HOURS MEAN TIME BETWEEN FAILURES EQUALS 230120+4375 HBURS TOTAL FALLURE RATE EQUALS DESIGN FAILURE RATE GOAL

12.00000 FAILURES PER MILLIUN HOURS

F-185

MOTORBLA, INC. FAILURE RATE DETERMINATION

MODEL ABSITIBNING SET 25. C TEMP ACOU-DPU MEDULE PKUJECT 3995-113 DATE APR 210171

COMPOVENT DESCRIPTION	YT9	STRESS IN PERCENT	FACTOR	BASIC FAILURE RATE	FAILURES PER MILLIBY HRS.	F.R. SBURCE	NUTES
CAPACITER, CER, CK	0.00		1.00	51400		47.40	
CAPACITEM, T C LER, CC	2		00.1	0.0075	00400	7770	
	20.0	36	1.40	25000	• 01449	2174	
CAPACITOR, SLU TANT, CSR	0.0		1.00	•11000	•05500	217A	
COIL, AUJIE	1.0		1.50	•20006	•30000	217A	
COIL, RF	3.0		1.00	• 22000	•66000	217A	
S INTEGRATED CINCUIT, DIGITAL	41.0		1.00	00004.	4.92000	217A	
INTEGRATED CINCUIT, LINEAR	12.0		1.00	00004.	4 · 800u3	217A	
* RESISTER, FIXED CARBON COMPOSITION	54.0		6.03	•00350	•11340	217A	
RESISTER, FIXED METAL FILM	3.6		•03	•12000	• 02880	217A	
TAANSFORMER, AF	O•0		1.50	•22000	• 66000	217A	
TAANSISTOR, SILICON APA, 0-1 MATI	1.0	<u>ع</u> و	1.50	•25500	• 38250	217A	

12.28813 FAILURES PER MILLION HOURS TOTAL FAILURE RATE EGUALS

MEAN 114E BETWEEN FAILURES EGUALS 81379-3125 HBURS

21.00000 FAILURES PER MILLIUN HOURS DESIGN FAILURE RATE GBAL

o o F-186

M6T8R8LA, INC. FAILURE RATE DETERMINATION

MODEL POSITIONING SET	
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	25. C
SPU PWR SUP	TEMP
MODULE	
CT 3995+113	DATE APR 21, 171
PKBJECT	DATE

			STRESS IN		BASIC	FAILURES PER	F.R.	
	COMPONENT DESCRIPTION	QTY	PERCENT	FACTBR	FAILURE HATE	MILLION HRS.	SBURCE	MOTES
	CAPACITOR, SLU TANT, CSR	0•9	ာ္တ	1.00	.11690	.06600	217A	
	CAPACITOR, FOIL TANT, CL	3.0	30	1.00	00990•	•13200	217A	
	COIL, AUDIO	1.0	30	1.50	• 20000	•30000	217A	
	DIBDE, SILICEN, 0-1 MATT	15.0	30	1.50	• 25500	5 • 73750	217A	
	RELAY, HALF CRYSTAL CAN	1.0	30	2 - 50	•00310	• 00775	217A	
\$ *	RESISTAR, FIXED CARBON COMPOSITION	19.0		6.00	•00350	• 03990	217A	
84	RESISTOR, FIXED METAL FILM	2.0	30	•03	•12000	· 00007	217A	
	TRANSFORMER, POWER	1.0	30	1.50	• 22000	• 33000	217A	
	TRANSISTUR, SILICEN APL, G-1 AATT	4.0	30	1.50	. 25500	1.53000	217A	
-1	TRANSISTUR, SILICON VPV. 1-50 WATT	1.0	30	1.00	.51000	•51000	217A	
	TRANSISTOR, SILICON PAP, 0-1 MATT	3.0	30	1.50	• 67000	0	217A	
	ZENER DIBDE, 0-1 MATT	3.0		1.00	•77000	2.31000	2174	
	CAPACITOR, CER, CK	3.0		1.00	•00512	•01537	217A	
Ĭ	CONNECTOR, 15 PINS	ູນ		1.10	.34300	•18865	217A	

14.18224 FAILURES PER MILLION HOURS 46.00000 FAILURES PER MILLIAN HBURS 70510 6875 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FAILURE RATE EQUALS DESIGN FAILURE RATE GOAL +

MOTORBLA, INC. FAILURE RATE DETERMINATION

MODEL POSITIONING SET	
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	25. C
MODULE DPU WORD CONTROL	TEMP
PR9UECT 3995-113	DATE APR 210171

			STRESS IN	~	BASIC	FAILURES PER	F. 8.	
	COMPONENT DESCRIPTION	K L 3	GTY PERCENT FACTOR	FACTBR	FAILURE RATE	MILLIBY HAS.	SBURCE	NOTES
	CAPACITUM, CEM, CK	15.0		1.00	• 60512	•07667	217A	
	CONVECTOR, 36 PLAS	1.0		1.10	1.22500	1.34755	217A	
S	SS INTEGRATED CINCUIT, DISITAL	0.44	<u>ي</u>	1.00	000004	5.28000	217A	
S	S+ RESISTOR, FIXED CARBON COMPOSITION	2.0		6 • 30	•00320	.0105	2174	

6.71486 FAILURES PER MILLION HOURS

13.00000 FAILURES PER MILLIUN HOURS

MEAN TIME BETWEEN FAILURES EQUALS 143923.4375 HOURS

DESIGN FAILURE RATE GOAL

F-188

TOTAL FAILURE RATE EGUALS

MOTGROLA, INC. FAILURE RATE DETERMINATION

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DPU MS& BUTPUT	TEMP
MS	
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MODULE	
T 3995-113	DATE APR 21,171
PRBJECT	DATE

		STRESS IN	¥	BASIC	FAILURES PER	2	
COMPONENT DESCRIPTION	¥T2	GIY PERCENT FACTOR	FACTOR	FAILURE RATE	MILLIBN HRS.	SBURCE	AUTES
CAPACITUM, CEM, CM	16.0		1.00	•03512	• 08200	217A	
CONNECTORS 36 PING	7.0		1.10	1.22500	1.34753	2174	
S. INTEGRATED CINCUIT, DISITAL	47.0	30	1.00	00004	5.64000	217A	
S+ RESISTOR, FIXED CARBON COMPOSITION	18.0		00.9	•03350	•03780	217A	

7.10728 FAILURES PER MILLIBN HOURS TOTAL FAILUNE RATE EGUALS

MEAN TIME BETWEEN FAILURES EQUALS 140700.7500 HBURS

13.00000 FAILURES PER MILLION HOURS DESIGN FAILURE RATE GOAL

MOTORE ANTE DETERMINATION

JATE AP4 21,171		TEAP		7€MP 25. C			
COMPONENT DESCRIPTION	Y TO	STRESS IN PERCENT	FACTBR	BASIC FAILURE MAIE	FAILURES PER MILLIBN ARS.	F.R. SBURCE	NUTES
CAPACITUM, CEN, CK	15.0		1.00	.00512	•07687	2174	
NVECTOR, 36 PIZS	1.0		1.10	1.22500	1034755	217A	
INTEGRATED CIRCUIT, JISITAL	0.94	30	1.00	00004.	5.52000	217A	
RESISTOR. FIXED CARBON COMPOSITION	0.9		00.9	•00350	•01263	2174	

6.95695 FAILURES PER MILLION HOURS	MEAN TIME BETWEEN FAILURES EQUALS 143741.1250 HOURS	13.00000 FAILURES PER MILLION HOURS
TETAL FAILURE RATE EGUALS	MEAN TIME BETWEEN FAILURES	DESIGN FAILURE RATE GBAL

	MOTORBLA, INC.	FAILURE RATE DETERMINATION

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	COMPONENT DESCRIPTION	× TO	STRESS IN GITY PERCENT	FACTOR	HAILJRE RATE	FAILURES PER MILLION HRS.	SBURCE	NOTES
	CAPACITUM, CEM, CK	14.0		1.00	•00512	• 57175	2174	
	CONNECTURA 36 PINS	1.0		1.10	1.22500	1 • 3 4 7 5 3	217A	
S	INTEGRATED CINCUIT, DISITAL	0.44		1.00	00004.	5.28000	217A	
*5	RESISTOR, FIXED CARBON COMPOSITION	20.0	30	00.9	•00320	• 04200	2174	
	CAPACITUR, SLU TANT, CSR	1.0		1.00	•11000	•01100	217A	

6./5223 FAILURES PER MILLION HOURS 13.00000 FAILURES PER MILLIUN HOURS MEAN TIME BETWEEN FAILURES EQUALS 148099-2500 HBURS 19TAL FAILURE RATE EGUALS DESIGN FAILURE RATE GOAL MOTORCIA INC. FAILURE MATE DETERMINATION

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	(A)		1.10	373+0•	.08800	217A	
Correction 15 place	\$	ာဗ	1.10	·34300	·18865	2174	
CONNECTER, 36 PINS	7.0		1.10	1.22500	9 • 43251	2174	
CONNECTORS 20 PINS	• •		1.10	• 48600	•26730	217A	

FAILURES EGUALS 100236.0000 HBURS	MEAN TIME BETWEEN FAILURES EQUALS 100236.0000 HBURS PRETER FAILURE DATE GRAI 27.00000 FAILURES PER MILLIAN HBURS	
		FAILURES EGUALS

MOTERBLA, INC. FAILURE RATE DETERMINATION

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PRBJECT 3995-113 MBJJLE MEMBRY PKR SUP MBJEL DATE APR 21,171 TEMP 25. C

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	CAPACITON, SLU TANT, CSR	•	30	1.00	•11030	• 06603	17
	CAPACITER, FUIL TANT, CL	S W	30	1.00	00990•	• 13200	217A
	COIL, AUDIS	1.0		1.50	• 20000	• 30000	17
	DIBDE, SILICON, 0-1 MATT	15.0		1.50	• 25500	5.73750	17
		0.1		2 • 50	•00310	• 00775	17
\$		19.0	30	၁	• 00350	• 03950	17
\$	RESISTOR, FIXED METAL FILM	2.0	30	•03	•12000	•0000	17
	R. PONER	1.0	30	1.50	• 22000	• 33000	17
	SILICEN APA		<u>ع</u>	1.50	• 2550	1.53000	17
	SILICS APA	•	30	1.00	•51600	•51303	17
F	TRANSISTUR,	3.0	30	1.50	•67650	•	
-	ZENER DIBDE, 0-1 AATT		30	1.00	•77000	31	17
19	-	3.0	30	1.00	•00518	•01537	17
3			30	1.10	·34300	•18865	217A

14-16224 FAILURES PER MILLISN HOURS 70510 6875 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FALLURE RATE EGUALS

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PRBJECT 3995-113	DATE AP4 21,171

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CAPACITOR, CEN, CK	0.0		1.00	•00512	• 02562	217A	
CAPACITUM, SLU TANT, CSR	17.0		1.00	011000	•18763	217A	
CONNECTOR, 10 PINS	0.6	30	1.10	.22200	2-19763	217A	
CONNECTOR, 20 PINS	15.0		1.10	• 48600	8 • 01900	217A	
DIBDE, SILICBN, C-1 AATT	50.08		1.50	• 255vc	19-12493	217A	
•	41.0		1.00	00004.	16.39999	217A	
INTEGRATED CIRCUIT, LINEAR	41.0		1.00	00004.	16.39999	217A	
RESISTOR, FIXED METAL FILM	92.0		•03	.12000	•33120	217A	
RESISTORY FIXED WIRE ABUND	21.0		1.00	·94750	19.89743	217A	
TRANSISTOR, SILICON APL, C-1 AATT	14.0		1.50	•25500	5.35560	217A	
ZENER DIUDE, 0-1 NATT	9°C		1.00	•77000	1.54000	217A	
CORES, FERRITE	201.0		1.00	• 00005	• 49922	217A	
CORES, FERRITE	0.666		1.00	200000	1 • 59998	217A	

91.57724 FAILURES PER MILLIBN HOURS 110.00000 FAILURES PER MILLIUN HOURS 10919.7422 HBURS MEAN TIME BETWEEN FAILURES EQUALS TOTAL FALLUKE RATE EGUALS DESIGN FAILURE RATE GBAL

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S PER F.K. HRS. SBURCE	D 217A
FAILURES PER E MILLION HRS.	.11253
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STRESS IN K GTY PERCENT FACTOR	1.60
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COMPONENT DESCRIPTION GIY	CAPACITON VAN AIN CT

NOTES

.1125G FAILURES PER MILLIBN HBURS MEAN TIME BETWEEN FAILURES EQUALS 8888892.0000 HOURS TETAL FAILURE RATE EGUALS

MUTEROLA INC. FAILURE RATE DETERNIVATION

SET, AIR		FAILURES PER FOR. MILLIBY ARS. SBURCE NOTES	2.42000 .20020 217A 1.34750 217A 1.75000
MEDEL PESITION SET, AIR	25• C	BASIC FAIL FAILURE RAIE MILL	.22000 .13200 .22500 .25500 .25000
MEDULE CONTROL & MONITOR	TEMP 25	STRESS IN A GTY PERCENT FACTOR	11.0 30 1.0 30 1.0 30 7.0 30 1.10
PREJECT 3995-113	DATE APR 21,171	COMPONENT DESCRIPTION	COIL, RF CONNECTOR, 8 PINS CONNECTOR, 36 PINS SWITCH, TOGGLE OR PUSHBUITON

F-19	6

5.71770 FAILURES PER MILLION HOURS

25.00000 FAILJRES PER MILLION HOURS

17+895+4375 HBURS

MEAN TIME BETAEEN FAILURES EQUALS

DESIGN FAILUNE RATE GBAL

TOTAL FAILURE RATE EGUALS

LUTES SBURCE P . K. 2114 2174 RADC 217A 2174 217A FAILURES PER MILLIBY HRS. MODEL AIRBORNE POS SET .03090 .26650 .12000 •02665 •90200 •06753 3.23400 1.58400 •00000 3.90150 3.44000 •01000 • 30000 6.40000 000000+ • 50000 •00775 •61953 •00169 1.89500 6 39000 C0000 · + •33000 • 05025 04004. 1 • 60380 3.82500 3.34251 • 60000 3.30000 •05361 FAILURE KATE •00773 **• 00512** •00052 **• 00102** •11000 •02250 •22000 000000 .18200 • 48600 •02000 2.55000 •25500 • 43000 .01000 • 10000 000004. 000004. **50000** •00310 •00350 •12000 33.42499 •07100 •25000 .30000 .22000 .16750 .01000 94750 BASIC J 25. FAILURE RATE DETERMINATION FACTBR CO • 1 1.40 00 - 1 2.00 1.00 00 • 1 0001 1.10 1.00 1.00 1.00 2.50 CO . 1 ..10 1.10 1.00 •75 1.50 1.00 1.00 1.00 1.00 1.50 RUBIDIOM FREQ STO 00.9 •03 10 8.00 1.00 1.50 1.00 MOTOROLA, INC. TEMP STRESS IN PERCENT 00000 295.0 0.4 52.0 15.0 13.0 82.0 3.0 0.64 8.0 1.0 3.0 16.0 10.0 1.0 1.0 47.0 2.0 5.0 0.91 5.0 0.44 36.0 1:0 QTY HEDOLE RESISTOR, FIXED CARBON COMPOSITION RESISTOR, NW VAR. LEAD SCREW ACT. RESISTOR'S NON-WW VAR. L. S. ACT. PRBJECT 3995-113 BAITCH, TOGGLE BR PUSHBUTTON AP4 21, 171 INTEGRATED CINCUIT, JISITAL INTEGRATED CINCUIT, LINEAR RESISTOR, FIXED HETAL FILM RESISTORA FIXED WIRE MOUND COMPONENT DESCRIPTION DIBDE, GERMANIUM, 0-1 MATT S DIBDE, SILICON, 0-1 MATT DIBDE, SILICON, 1-50 WATT SLO TANT, CSR RELAY, HALF CRYSTAL CAN ALUM ELECT. VAN CER, CV MYLAR, CTH GLASS, CY MICA CM FD-THRU CER, CK CONNECTOR, 20 PINS TRANSFORMER POWER SNIA 8 FILTER, FEED THAU DATE CRYSTAL, BUARTZ IL (K PRANSFORMER, CONVECTBA CONVECTOR CAPACITOR CAPACITOR CAPACITOR CAPACITOR CAPACITOR 7-ER41578-CAPACITURA CAPACI 1942 CAPACITURA C916, 2F HETER 53 3 3 23 F-197 3

	TRANSISTOR,	FIELD EFFE	3.0	30	1.50	•67000	3.01500	2174
	TRANSISTBR,	GERMANIU4 :	2.0	<u>ه</u>	1.000	2.1.000	4 • 20000	2174
53	-	SILICEN AP	0.00	3	1.50	. 25500	7.11453	217A
	TRANSISTOR,	SILICAN AP	10.0	3.	1.00	.51000	5 10000	2174
S		SILICAN AND	11.0	'n	1.50	•67000	3.31650	217A
	TRANSISTUR		°.0	30	1.33	1.34000	2.665333	2174
	VARICAP		0.4	က္က	C:: • 1	.25500	1.53300	2174
	ZENER DIBDE	S 0-1 AATT	0.8	၁ဗ	1.33	.77000	6.16000	217A
	ZENER DIBDE	ATT	1.0	ე ლ	1.00	•77656	•77330	2174

85.14833 FALLURES PER MILLION HOURS	11744.2109 HBURS	25.00000 FAILURES PER MILLION HOURS
85	EGUALS	25.
THIAL FALLINE RATE ETUALS	MEAN TIME BETAEEN FAILURES EGUALS 11744.2109 HBURS	DESIGN FAILURE RATE GBAL

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25. € BUTSIDE CABLES TEMP MADULE PRBJECT 3995-113 DATE AP4 21,171

MADEL LAPDS SYSTEM

COMPONENT DESCRIPTION

FAILURES PER MILLIBN HRS. STRESS IN A BASIC OTY FERCENT FACTOR FAILURE MATE

. 44440 FAILURES PER MILLION HOURS

217A 217A

07400

.18200

NUTES

F. K. SBURGE

CONNECTOR, RF

MEAN TIME BETWEEN FAILURES EQUALS 2250224.0000 HBURS

TOTAL FAILURE RATE EGUALS

MOTGROLA, INC. FAILURE RATE DETERMINATION

TETAL OF ALL MODULES PRBJECT 3995-113

DATE AP4 210'71

TEMP

25 €

459-64917 FAILURES PER MILLIBN HBURS 2175.5723 HBURS MEAN TIME BETWEEN FAILURES EQUALS TETAL FAILURE RATE EQUALS

APPENDIX G

MAINTAINABILITY PREDICTION DATA

1.

Data developed in performing the maintainability predictions are included in this appendix. This includes a complete set of maintenance task flow diagrams, task time summaries, and supporting data.

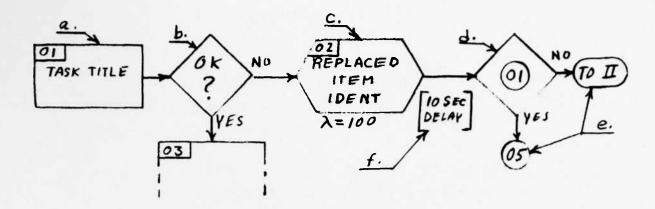
2. PREDICTION PROCEDURE

The maintainability prediction was performed using a task flow analysis and time estimation technique involving the following steps:

- a. A maintenance task flow diagram is proposed using the symbology illustrated in Figure G-1. The chart identifies each action performed and logical decision that must be made during each different maintenance action sequence. This diagram contains the following.
 - (1) Identification of each action that consumes maintenance time.
 - (2) Identification of each logical decision and action taken following the decision.
 - (3) Failure rates of each module with respect to given failure symptoms and maintenance task sequences.
- b. Maintenance tasks are summarized on a worksheet and task time are summed to determine M_{CT} values for each module and failure mode. These values are then weighted by the relative failure rate of the module for the respective failure mode, the weighted values summed, and the results divided by the total failure rate to obtain an \overline{M}_{CT} estimate.

3. ASSUMPTIONS

The maintainability prediction is based on the following assumptions:



LEGEND:

- A. PREPARATION OR TEST TASK. BOX CONTAINS:
 TASK IDENTIFICATION NUMBER
 DESCRIPTIVE TASK TITLE
- b. DECISION. BOX INDICATES TYPE OF DECISION MADE AND NEXT ACTION TAKEN FOLLOWING THE DECISION
- C. REPLACEMENT TASK, BOX CONTAINS:

 TASK IDENTIFICATION NUMBER

 IDENTIFICATION OF REPLACED ITEM

 REPLACED ITEM FAILURE RATE (X)
- d. RE-TEST ROUTINE. BOX INDICATES ACTION TAKEN FOLLOWING A REPLACEMENT. THE ABOVE EXAMPLE SAYS:

RE-PERFORM TASK OF HAKE OK" DECISION INDICATED BY BLOCK L.

GO TO TASK 35 IF OK" DECISION IS REACHED

GO TO SUBROUTINE II IF "NOT OK" DECISION IS REACHED

- e. FLOW CHART ENTRY POINTS! ARABIC NUMERALS INDICATE A TASK IDENTIFICATION NUMBER; ROMAN NUMERALS INDICATE AN ENTRY POINT IN ANOTHER SUBROUTINE
- f. TIME DELAYS NOT ASSOCIATED WITH NUMBERED TASKS. E.G., TIME
 REQUIRED FOR TEST SET TO INDICATE AN ERROR AFTER
 ONE HAD BEN ENCOUNTERED

Figure G-1. Maintenance Task Flow Diagram Symbology

- a. Maintenance time starts after units are placed on the maintenance bench and all necessary equipment and spares are immediately available.
- b. All test equipment, including the TCS and auxiliary test equipment are turned on and ready for tests to begin. The time required to connect the unit to the test set is considered as part of the maintenance time. However, warm-up time, such as the time required for oscillator or frequency standard stabilization, is not considered.
- c. A maintenance action is completed when correction of the specific failure under consideration has been verified and the equipment returned to serviceable condition.

 Additional time that may be required to completely check out the remaining functions of the unit are not considered as part of a given corrective maintenance action.
- d. The following test equipment is assumed to be available:

 Test and Calibration Set. This provides facilities to
 test all digital circuitry of the DPU and the overall
 operation of the RTU.

RTU Test Box. This provides test point "break-out" capability for using auxiliary test equipment.

Oscilloscope. This is used for observing certain RTU signal status indications.

Multimeter. This is used for measuring power supply and signal voltage levels.

4. MAINTAINABILITY PREDICTION DATA

Data prepared in performing the maintainability prediction are presented in the following sections of this appendix:

rigure G-2.	Positioning unit maintenance rlow
	Diagram
Figure G-3.	RTU Maintenance Flow Diagram (Receive
	Functions)
Figure G-4.	RTU Maintenance Flow Diagram (Transmit
	Functions)

Figure G-5. Reference Position Unit Maintenance Flow Diagram

Figure G-6.	Positioning Unit Supplementary
	Maintenance Flow Diagram (P7 Message
	Sequence)
Table G-1.	Corrective Maintenance Task Time
	Estimates
Table G-2.	Positioning Set Task Time Summary
Table G-3.	Reference Position Set Task Time
	Summary (Defined Portions Only)
Table G-4.	RPS Fault Detection Time
Table G-5.	Elemental Task Times

5. REFERENCE POSITION SET MAINTAINABILITY ESTIMATE

Table G-3 summarizes the maintainability prediction data for those portions of the RPS that have been sufficiently defined to date. However, the DPU has not been defined sufficiently to associate functions and failure modes with physical modulization. Therefore, the predictions cannot be completed for these portions.

An estimate of the maintenance time for the DPU is made by determining the approximate times expended before different categories of failures are detected by the TCS. In general, any DPU failure involves one of the following types of operation:

- a. Decoding and responding to commands.
- b. Generating and transmitting commands.
- Storing data in memory and reading data out of memory.

Table G-4 indicates the approximate minimum, maximum and average times that are required to detect failures in each of these categories. This includes the time required for the TCS to lock up on an error that would be detected at the earliest possible and latest possible events of the test cycle. Assuming two modules would be replaced before the failure was corrected, the test would be performed three times for an "average" DPU failure; twice for fault isolation and once for final check. Thus, the total troubleshooting time for a given categroy of failure is estimated to be the three times the average time indicated in Table G-4.

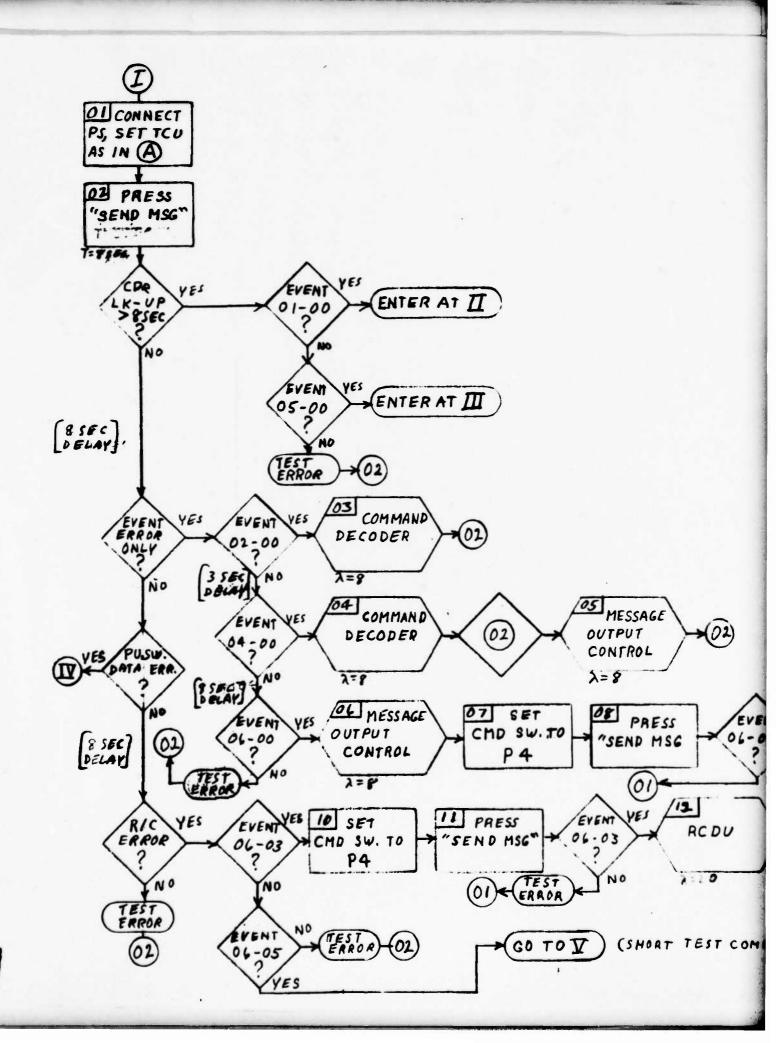
It is assumed that there are 9 logic modules, each having a failure rate similar to those of the PS, or approximately $8 ext{ f/10}^6$.

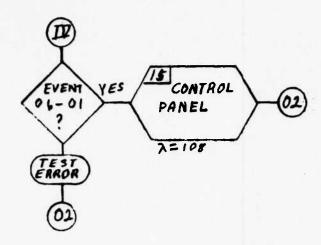
The memory failure rate has been predicted to be $98 ext{ f/10}^6$. Assuming two modules are replaced on the average in locating a failure, and set-up time is $15.7 ext{ minutes}$ (tasks 60, 61, and 64) the DPU maintenance time is calculated as:

$$\mathbf{M}_{CT} = \frac{9[15.7 + 3(1.95)](8) + [15.7 + 3(3.9)]98}{72 + 98}$$
= 24.8 minutes

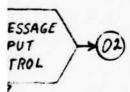
Combining this with the predicted values for the defined portions of the RPS (Table G-3) gives an estimate of \overline{M}_{CT} for the RPS as:

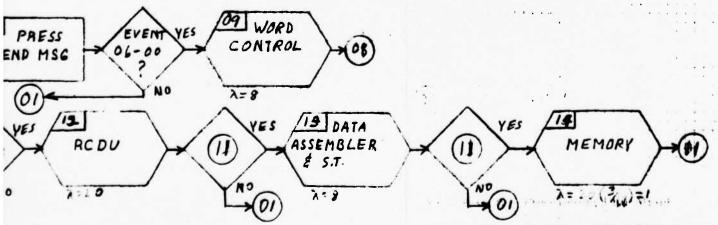
$$\frac{31.2 \times 639 + 24.8 \times 170}{809}$$
 = 29.8 minutes





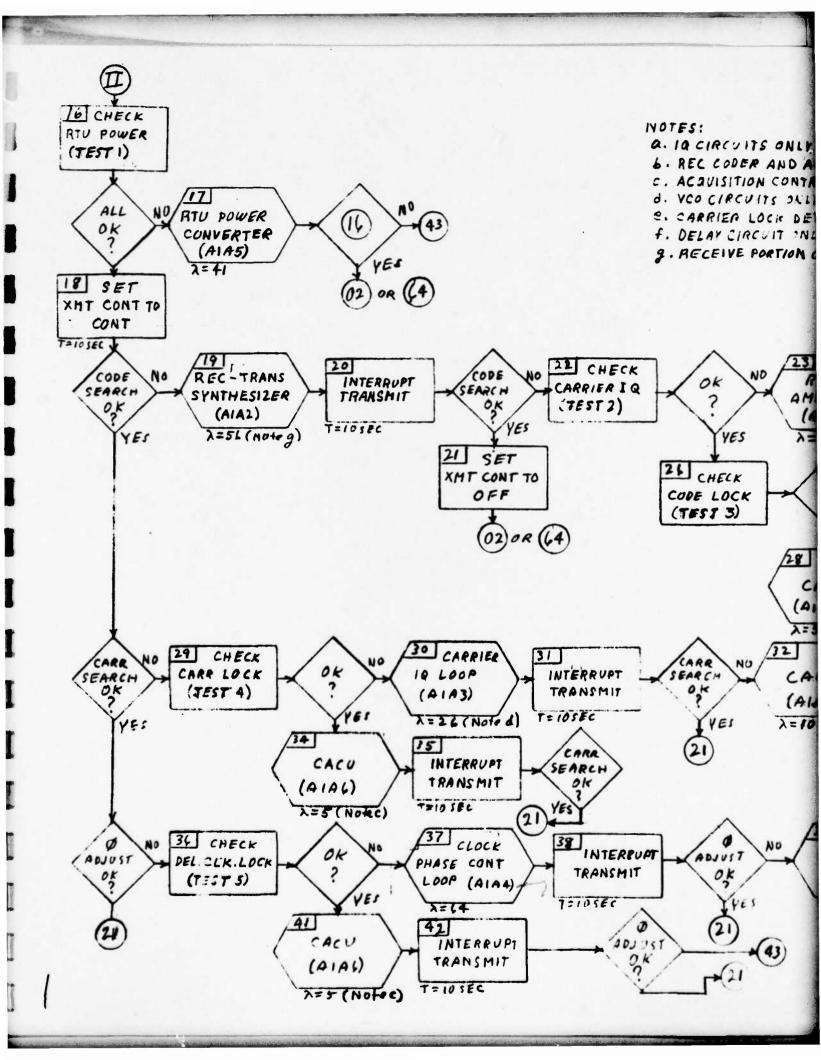
A TOU SWITCH SETTINGS	
SWITCH	SETTING
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CODE SELECT	AS QH. PU
PU SW. DATA	AS DESIRE
DIGITAL MSG	AS DESIRED
UUT	PU/DDU.
ALTIMETER DATA	NOT USED
COMMAND	PI
INTERVAL	2
FLAG	4
XMIT CONTINUOUSLY	OFF





(SHOAT TEST COMPLETED)

Figure G-2. Positioning Unit Maintenance Flow Diagram



CUITS ONLY
OBER AND ACO. CONT. ONLY
SITION CONTROL ONLY
IRCUITS ONLY
ER LOCK DETECTOR ONLY
CIRCUIT ONLY
IVE PORTION ONLY

TESTS: (RTU TEST BOX SW. POSITIONS)

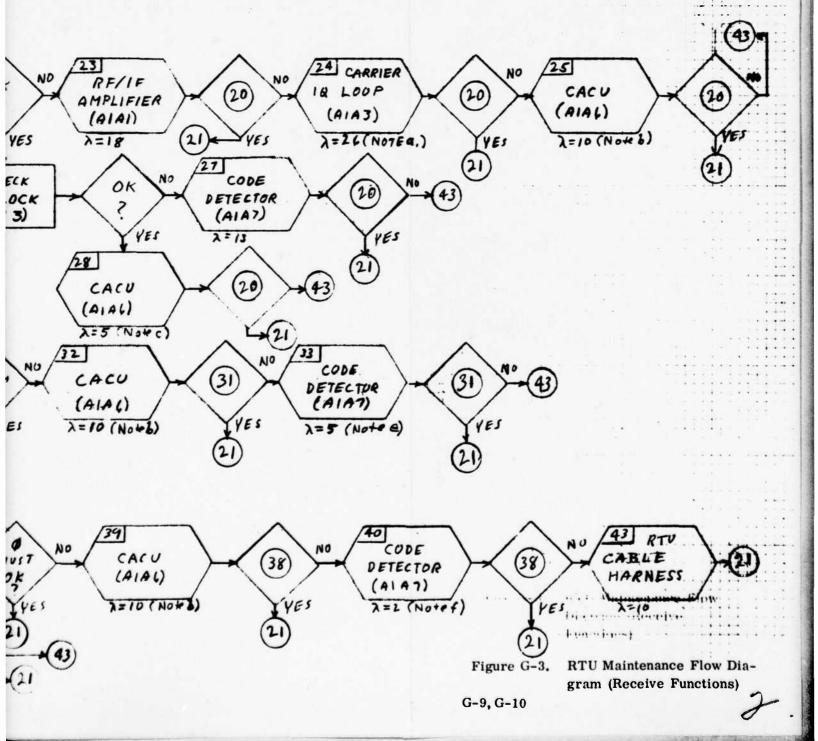
1. A-1, A-2, A-3, A-4, A-5, A-6

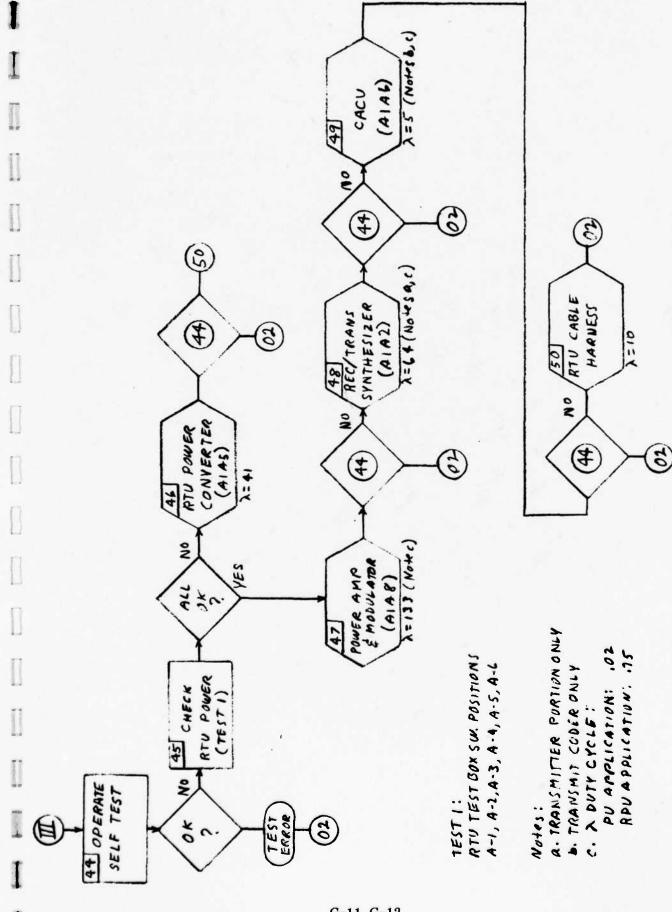
2. A-7, A-8, A-9

3. A-10

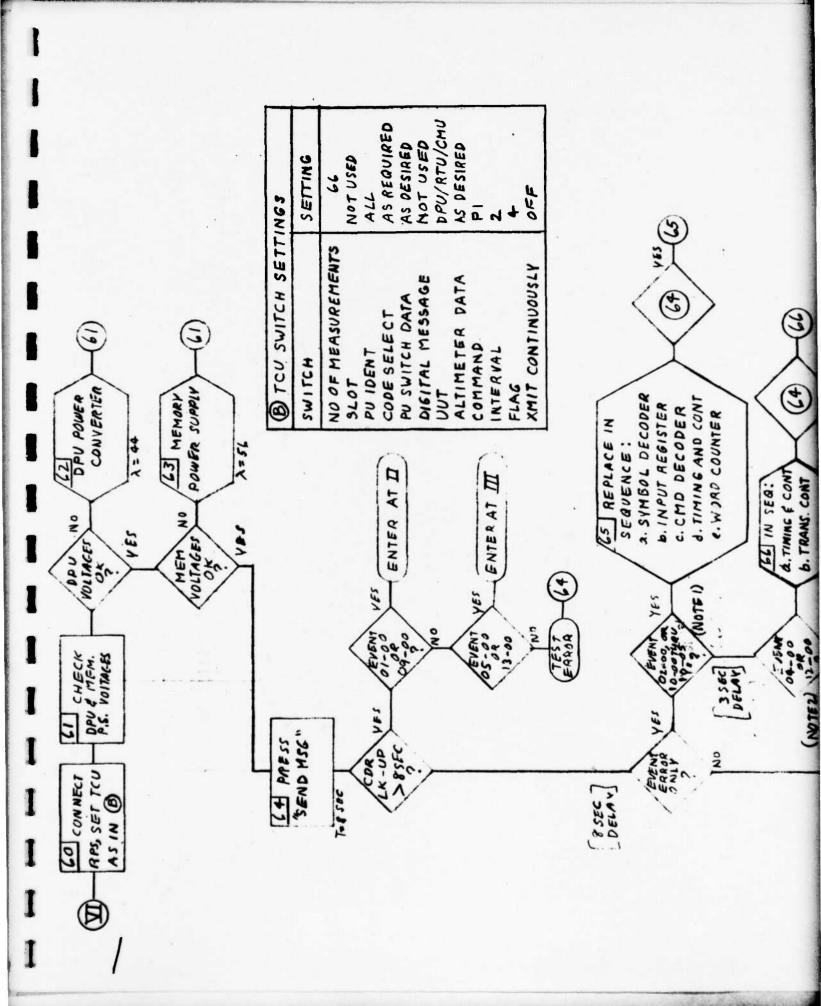
4. A-11

5. A-12





RTU Maintenance Flow Diagram (Transmit Functions) Figure G-4.



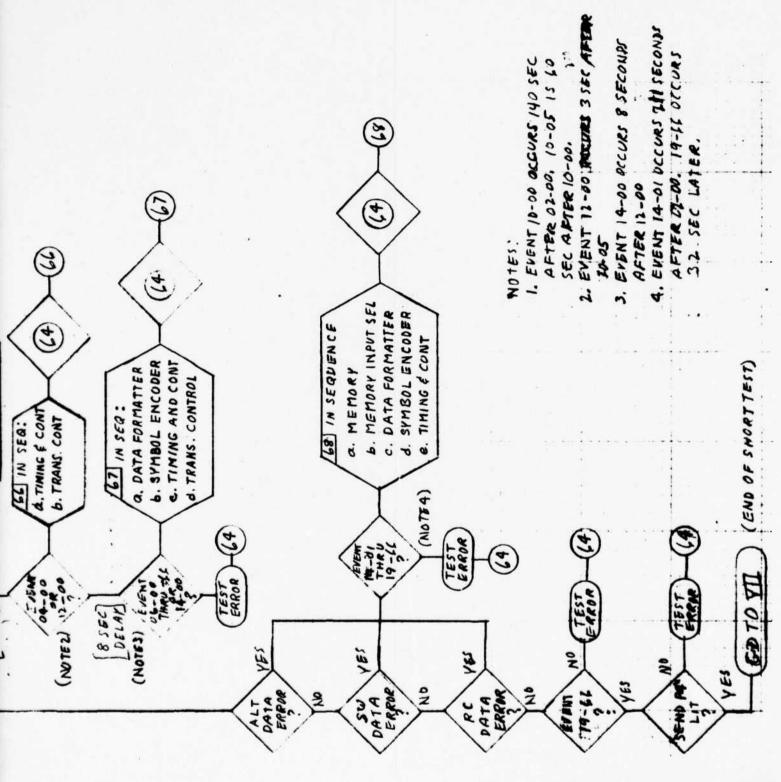


Figure G-5. Reference Position Unit Maintenance Flow Diagram

5

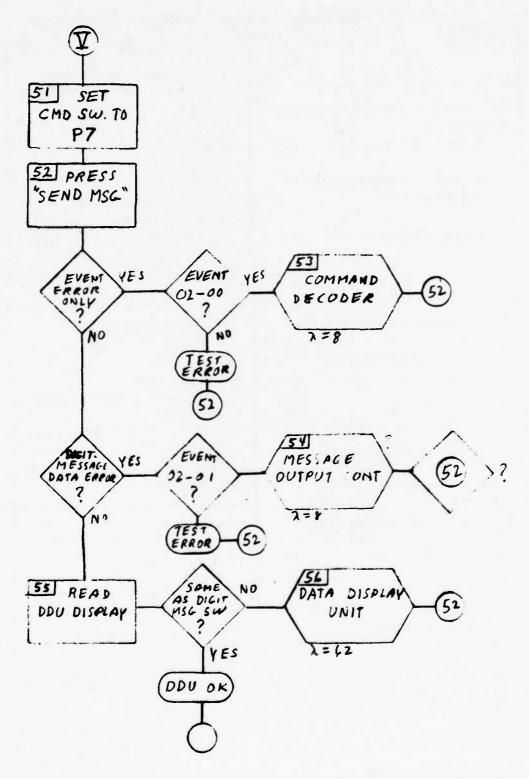


Figure G-6. Positioning Unit Supplementary Maintenance Flow Diagram (P7 Message Sequence)

Table G-1. Corrective Maintenance Task Time Estimates

Task No.	Task	Task Element	Time (Min)
01	Connect PU to Test Set, set TCU Switches		
	Remove Unit from Case	Latches (4)	0.1
		Captive Screws (4)	2.4
	Remove Protective Cover	Loose Screws (4)	3.2
	Connect to TCS	Multipin Connector (3)	5.0
		RF Connector (2)	0.8
	Operate Switches	Pushbutton on Toggle Sw (12)	1.2
		Rotary Switch (3)	0.6
		Total	13.3
02	Press "Send Message"	Press Switch +8 sec	0.3
03	Replace Command Decoder	Unplug PCB	0.9
		Exchange PCB	0.2
		Total	1.1
04	Replace Command Decoder	Same as 03	1.1
05	Replace Message Output Cont	Same as 03	1.1
06	Replace Message Output Cont	Same as 03	1.1
07	Set Cond Switch to P4	Rotary Switch	0.2
08	Press "Send Msg"	Press Switch +10 sec	0.3
09	Replace Word Control	Same as 03	1.1
10	Set End Switch to P4	Same as 07	0.2
11	Press "Send Msg"	Same as 08	0.1
12	Replace RCDV	Same as 03	1.1
13	Replace Data Assemb	Same as 03	1.1
14	Replace Memory	Same as 03	1.1

Table G-1. Corrective Maintenance Task Time Estimates (Cont)

Task No.	Task	Task Element	Time (Min
15	Replace Control Panel	Cannon Connector Exchange Panel Set Switches (10)	1.6 0.2 1.0
		Total	2.8
16	Check RTU Power	Rotate Switch (6 positions) Meter measurement (6)	0.7
		Total	2.1
17	Replace RTU Power Conv	Cannon Connector (2) Captive Screw (4) Exchange Module	6.6 4.8 0.2
		Total	11.6
18	Set Xmit Cont to CONT	Flip Switch Wait 10 seconds	0.1
		Total	0.3
19	Replace Rec-Trans Synth	Cannon Connector RF Connector (6) Captive Screw (2) Exchange Module	3.3 3.0 2.4 0.2
		Total	8.9
20	Interrupt Transmit	Press Button Wait 10 seconds	0.1
		Total	0.3
21	Set Xmit Cont to OFF	Flip Switch	0.1
22	Check Carrier IQ	Rotate Switch (3 positions) Scope measurement (2) Mcter mcasurement	0.4 0.7 0.4
		Total	1.5

Table G-1. Corrective Maintenance Task Time Estimates (Cont)

Task No.	Task	Task Element	Time (Min
23	Replace RF/IF	Cannon Connector	3.3
		RF Connectors (5)	2.5
		Captive Screws (2)	2.4
		Exchange Module	0.2
		Total	8.4
24	Replace Carricr IQ Loop	Cannon Connector	3, 3
		RF Connectors (6)	3.0
		Captive Screws (2)	2.4
		Exchange Module	0.2
		. Total	8.9
25	Replace CACU	Cannon Connector	3.3
		RF Connector (9)	4.5
		Captive Screws (4)	4.8
		Exchange Module	0.2
		Total	12.8
26	Check Code Lock	Rotate Switch	0.2
		Meter measurement	0.4
		Total	0.6
27	Replace Code Detector	Cannon Connector	3.3
		Captive Screws (2)	2.4
		Exchange Module	0.2
		Total	5.9
28	Replace CACU	Sec Task 25	12.8
29	Check Carrier Lock	Rotate Switch	0.2
		Meter measurement	0.4
		Total	0.6
30	Replace Carrier IQ Loop	See Task 24	8.9

Table G-1. Corrective Maintenance Task Time Estimates (Cont)

Task No.	Task	Task Element	Time (Min
31	Interrupt Transmit	See Task 20	0.3
32	Replace CACU	See Task 25	12.8
33	Replace Code Detector	See Task 27	5,9
34	Replace CACU	See Task 25	12.8
35	Interrupt Transmit	See Task 20	0.3
36	Check Delayed Clock Lock	Rotate Switch Meter measurement	0.2
		Total	0.6
37	Replace Clock Ph Cont Loop	Cannon Connector RF Connectors (6) Captive Screws (2) Exchange Module	3.3 3.0 2.4 0.2
		Total	8.9
38	Interrupt Transmit	See Task 20	0.3
39	Replace CACU	Sec Task 25	12.8
40	Replace Code Detector	See Task 27	5.9
41	Replace CACU	See Task 25	12.8
42	Interrupt Transmit	See Task 20	0.3
43	Rcplace RTU Cable Harness	Cannon Connectors (11) RF Connectors (34)	36.3 17.0
		Total	53.3
44	Operate Self Test	Pushbutton Wait 8 seconds	0.2
		Total	0.3

Table G-1. Corrective Maintenance Task Time Estimates (Cont)

Task No.	Task	Task Element	Time (Min)
45	Check RTU Power	See Task 16	2.1
46	Replace RTU Power Connector	See Task 17	11.6
47	Replace PA & Modulator	Cannon Connector RF Connector (3) Captive Screws (6) Exchange Module	3.3 1.5 7.2 0.2
		Total	12.2
48	Replace Rec-Trans Synth	See Task 19	8.9
49	Replace CACU	See Task 25	12.8
50	Replace RTU Cable Harness	See Task	53, 3
51	Set Cond Sw to P7	Rotate Switch	0.2
52	Press "Send Msg"	Press Button	0.1
53	Replace Command Decoder	Unplug-Plug PCB Exchange PCB	0.9
		Total	1.1
54	Replace Message Output Cont	Same as Task 53	1, 1
55	Read DDU Display	Digital Readout (10)	0.2
56	Replace DDU	Exchange Unit Multipin Connector	0.2
		Total	3.5
60	Connect RPS to Test Set, Set Switches Remove Units from Cases	Captive Screws (8) Slide Unit out (2) (est)	4.8

Table G-1. Correr, e Maintenance Task Time Estimates (Cont)

Task No.	Task	Task Element	Time (Min)
60 (cont)	Connect to TCS Operate Switches	Multipin Connector (4) RF Connector (2) Push Button on Toggle (12) Rotary Switch (3)	6.6 0.8 1.2 0.6
		Total	14.2
61	Check DPU & Memory Voltages	Meter measurements (5)	1.2
62	Replace DPU Power Converter	Unplug, Plug PCB Exchange PCB	0.9
		Total	1.1
63	Replace Memory P.S.	Captive Screws (4) Unplug-Plug Unit Exchange Unit	2.4 0.9 0.2
		Total	3.5
64	Press "Send Message"	Same as 02	0.3

Table G-2. Positioning Set Task Time Summary

Replaceable Item	Task #	Т	λ	ΣλΤ
Command Decoder	01	13.3		
(Decode S1)	02	0.3		
	Delay	0.3		
	03	1.1		
	02	0.3		
		15.3	8	122
Command Decoder	01	13.3		
(UUT Transmit on)	02	0.3		
	Delay	0.3		
	04	1.1		
	02	0.3		
		15.3	8	122

Table G-2. Positioning Set Task Time Summary (Cont)

Replaceable Item	Task #	Т	λ	Σλτ
Message Output Cont	01-04	15.0		
(UUT Transmit on)	02	0.3		1
(5.5.2.2.3.3.3.3.3.3.3.4.4.4.4.4.4.4.4.4.4.4	Delay	0.3		
	05	1.1		
	02	0.3		
		17.0	8	136
Message Output Cont	01-02	13.6		
(Encode S5)	Delay	0.4		
	06	1.1		
	07	0.2		
	08	0.3		
		15.6	8	125
Word Control	01-08	15.6		
(Encode S5)	Delay	0.4		
	09	1.1		
	08	0.3		
		17.4	8	139
RCDU	01	13.3		
	02	0.3		
	Delay	0.1		
	10	0.2		
	11	0.1	-	
	12	1.1		}
	11	0.1		
		15.2	20	304
Data Assemb	01-12 & 11	15.2		
(RC Error)	13	1.1		
	11	0.1		
		16.4	8	131
Memory	01-13 & 11	16.4		
(RC Error)	14	1.1		
	11	0.1		
		17.6	1	18

Table G-2. Positioning Set Task Time Summary (Cont)

Replaceable Item	Т	T	λ	Σλ'
Control Panel	01	13.3		
	02	0.3		
	Delay	0.3		
	15	2.8		
	02	0.3		
		17.0	108	1840
RTU Power Conv	01, 02	13.6		
(Receive Problem)	16	2.1		
	17	11.6		
	16	2.1		
	02	0.3		
		29.7	41	1220
Rec-Trans Synth	01-16	15.7		
(Receive)	18	0.2		
	19	8.9		
	20	0.2		
		25.0	56	1400
RF/IF Amp	01-20	25.0		
,p	22	1.5		
	23	8.4		
	20	0.2		
		35.1	18	640
Carrier IQ Loop	01-23 & 20	35.1		
(Code Search)	24	8.9		
(0110 -1101)	20	0.2		-
		44.2	26	1150
CACU	01-24 & 20	44.2		
(Code Search)	25	12.8		
(0)40 2042 011,	20	0.2		
		57.2	10	572
CACU	01-20	25.0		
(Status Output)	22	1.5		
(26	0.6		
	28	12.8		
	20	0.2		
		40.1	5	205

Table G-2. Positioning Set Task Time Summary (Cont)

Replaceable Item	Task #	Т	λ	Σλ
Code Detector	01-22	26.5		
(Code Search)	26	0.6		
(10.00	27	5.9		
	20	0.2		
		33.2	13	432
Carrier IQ Loop	01-18	15.9		
(Carrier Search)	29	0.6		
	30	8.9		
	31	0.3		
		25.7	26	670
CACU	01-31	25.7		
(Carrier Search)	32	12.8		
	31	0.3		
		38.8	10	388
Code Detector	01-32 & 31	38.8		
	33	5.9		
	31	0.3		
		45.0	5	225
CACU	01-29	16.5		
(Status Output)	34	12.8	_	
(Carried Carry)	35	0.3		
		29.6	5	148
Clock Phase Control	01-18	15.9		
	36	0.6		
	37	8.9		
	38	0.3		
		25.7	64	1640
CACU	01-38	25.7		
(Clock Adj)	39	12.8		
	38	0.3		
		38.8	10	388
Code Detector	01-39 & 38	38.8		
(Delay Circuit)	40	5.9		
(- 3-25)	38	0.3		
		45.0	2	90

Table G-2. Positioning Set Task Time Summary (Cont)

Replaceable Item	Task #	T	λ	Σλ
CACU	01-36	16.5		
(Status Output)	41	12.8		
	42	0.3		
		29.6	5	148
RTU Power Converter	01,02	13.6		
(Transmit Problem)	44	0.3		ł
	45	2.1		
	46	11.6		
	44	0.3		
		27.9	41	1140
PA and Modulator	01-45	16.0		
	47	12.2		[-
	44	0.3		l
		28.5	133	3790
Rec/Trans Synth	01-47 & 44	28.5		
(Transmit)	48	8.9		į.
	44	0.3		
		37.7	64	2420
CACU	01-48 & 44	37.7		
(Trans Code)	49	12.8		
	44	0,3		
		50.8	5	254
Totals			706	19,857
Totals	$\overline{M}_{ct} = \frac{19857}{706} = 28$	8.3 minutes	706	19,857
DDU	01-02	13.6		
	Delay	0.3		
	51	0.2		
	55	0.2		
	56	3.5		
Totals		17.8	62	1100

Table G-3. Reference Position Set Task Time Summary (Defined Portions Only)

Replaceable Item	Task #	Т	λ	ΣλΊ
DPU Power Converter	60	14.2		
	61	1.2		
	62	1.1		
	61	1.2		
		17.7	44	780
Memory Power Supply	60-61	15.4		
	63	3.5	1	
	61	1.2		
		20.1	56	1120
RTU Power Converter	60	14.2		
(Receive Problem)	61	1.2		
	64	0.3		
	16	2.1		
	17	11.6		
	16	2.1		
	64	0.3		
		31.8	41	1300
Rec-Trans Synth	60-64	15.7		
(Receive)	16	2.1		
	18	0.3		
	19	8.9		
	20	0.3		
		27.3	56	1530
RF/IF Amp	60-64, 16-20	27.3	F	
	22	1.5		
	23	8.4		
	20	0.3		
		38.5	18	690
Carrier IQ Loop	60-23 & 20	38.5		
(Code Search)	24	8.9		
	20	0.3		
		47.7	26	1240

Table G-3. Reference Position Set Task Time Summary (Defined Portions Only) (Cont)

Replaceable Item	Task #	Т	λ	ΣλΊ
CACU (Code Search)	60-24 & 20	47.7		
CACU (Code Search) CACU (Status Output) Code Detector (Code Search) Carrier IQ Loop (Carrier Search)	25	12.8		
	20	0.8		
		61.3	10	613
CACU (Status Output) Code Detector (Code Search) Carrier IQ Loop (Carrier Search)	60-20	27.3		
	22	1.5		
	26	0.6		
	28	12.8		
	20	0.3		
		42.5	5	212
Code Detector	60-22	28.8		
	26	0.6		
	27	5.9		
	20	0.3		
		35.6	13	463
Carrier IQ Loop	60-18	18.1		
	29	0.6)
	30	8.9		
	31	0.3		
		27.9	26	725
CACU (Carrier Search)	60-31	27.9		
	32	12.8		
	31	0.3		
		41.0	10	410
Code Detector	60-29	18.7		
	33	5.9		
	31	0.3		
		24.9	5	124
CACU (Status Output)	60-29	18.7		
	34	12.8		
	35	0.3		
		31.8	5	159

Table G-3. Reference Position Set Task Time Summary (Defined Portions Only) (Cont)

Replaceable Item	Task #	Т	λ	ΣλΊ
Clock Phase Control	60-18	18.1		
	36	0.6		
	37	8.9		
	38	0.3		
		27.9	64	1790
CACU (Clock Adj)	60-38	27.9		
•	39	12.8		
	38	0.3		
		41.0	10	410
Code Detector	60-39 & 38	41.0		
(Delay Circuit)	40	5.9		
,	38	0.3		
		47.2	2	94
CACU (Status Output)	60-36	18.7		
CACU (Status Output)	41	12.8		
	42	0.3		
·		31.8	5	159
RTU Power Converter	60-64	15.7		
(Transmit Problem)	44	0.3		
	45	2.1		
	46	11.6		
	44	0.3		
		30.0	41	1230
PA & Modulator	60-45	18.1		
	47	12.2		
	44	0.3		
		30.6	133	4070
Rec/Trans Synth	60-47 & 44	30.6		
(Transmit)	48	8.9		
	44	0.3		
		39.8	64	2550

Table G-3. Reference Position Set Task Time Summary (Defined Portions Only) (Cont)

Replaceable Item	Task #	Т	λ	Σλτ
CACU (Transmit	60-48 & 44	39.8		
Coder)	49	12.8		
	44	0.3		
		52.9	5	264
Totals			639	19,933

Table G-4. RPS Fault Detection Time

	Time After Starting Test			
Type of Operation	Minimum	Maximum	Average	
Decoding & Responding to Commands	0.1	3.0	1.55	
Generating & Transmitting Commands	0.4	3.8	2.0	
All Logic Modules	0.1	3.8	1.95	
Exercising Memory	3.8	4,0	3.9	

Table G-5. Elemental Task Times

Task Element	One-way Time	Data Source	
Fastener Operation			
Loose Screw with Washer	0.8	NAVSHIPS 94324	
DZUS Fasteners	0.05	NAVSHIPS 94324	
Captive Screw	0.60	NAVSHIPS 04324	
Latches	0.03	NAVSHIPS 94324	
Connector Operation			
Multipin Connector	1.65		
(Cannon Connector, etc.)			
(Plug-in)	(0.45)	MIL-HDBK-472	
(2 Captive Screws)	(1.20)	NAVSHIPS 94324	

Table G-5. Elemental Task Times (Cont)

Task Element		One-way T	ime	Data Source
RF Connector		Disconnect Reconnect		Motorola Timed Data
PCB		0.45		NAVSHIPS 94324
Module Exchange		0.20		
(Remove Module) (Place On Chassis)		0.05 0.15		Estimate MIL-HDBK-472
Task Element	1st Action	s	ubsequent	Data Source
Test Operations				
Observe Go-No-Go (or digital readout)	0.1		0.01	Estimated
Monitor Analog Reading (Meter)	0.4		0.2	Estimated
Monitor Digital Reading (Scope)	0.5		0.2	Estimated
Pushbotton or Flip Switch	0.1		0.1	Estimated
Rotate Knob	0.2		0.1	Estimated

